Various Industrial Mineral Commodities in Nova Scotia

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VARIOUS INDUSTRIAL MINERAL COMMODITIES IN NOVA SCOTIA

by

R. H. MacDonald

ABSTRACT

Nova Scotia possesses several industrial mineral commodities with excellent potential for development. The Various Commodities Project has attempted to identify, explore, promote and increase the database on deposits containing the commodities presently sought in the world marketplace. The 13 industrial minerals investigated are andalusite, barite, beryllium, brucite, celestite, garnet, graphite, limestone/dolomite, silica, spodumene, talc, titanium and wollastonite.

Each industrial mineral commodity is assigned a chapter and the mineralogy, uses, world producers and Nova Scotia potential of each are discussed. The project deals with the deposits which, in the author's opinion, have the best development potential. Time constraints and the elimination of minor occurrences of academic interest only, helped dictate this selection. Further study and investigative exploration are warranted on some promising Provincial deposits of commodities with existing markets and other known deposits of commodities presently not sought in the marketplace, but which could have future potential as demands change.

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CHAPTER 1. INTRODUCTION

The Various Commodities Project was initiated in May 1986 to better identify and increase the data base on several lesser known industrial mineral commodities within Nova Scotia having excellent potential for development. These include andalusite, barite, beryllium, brucite, celestite, garnet, graphite, limestone and dolomite, silica, spodumene, talc, pyrophyllite, titanium and wollastonite. The Project has been funded under the Canada-Nova Scotia Mineral Development Agreement. Many of the commodities are becoming more and more sought after in the world marketplace due to the ever changing technologies being developed and the continuous depletion of traditional resources.

Nova Scotia's unique geography, being almost completely surrounded by tidal water, having all points within 50 km of this tidal water and located near the world markets, all add to the viability of development of any of Nova Scotia's industrial mineral deposits. The stable political system, highly skilled and proven work force and established transportation infrastructure are all added incentives for development.

A wide suite of different industrial mineral commodities have been included in this project. Some commodities have been the focus of very extensive and detailed work in the past so a different approach was taken with these to avoid duplication of work. For example, the location, type and quality of most limestone and dolomite deposits were detailed by Murray (1975), therefore this project studied only limestone and dolomite deposits with excellent potential for development based on available reserves, high quality, location near markets and ease of extraction.

Other lesser known commodities occurring within the Province were also investigated. The use of silica as an abrasive medium is decreasing due to health concerns and is being replaced by garnet. Wollastonite is becoming popular as a substitute for asbestos. Both of these replacement commodities occur in deposits with development potential within Nova Scotia and investigative work was completed on both.

A few commodities known to occur in the Province, but with questionable development potential were investigated to encourage further exploration by private interests. As an example, the heavy mineral sands of the Shubenacadie River were sampled and the mineralogy examined. Time and budget restraints limited the number of commodities and the extent of work completed on each.

A program of bulk sampling of difficult to assess deposits was initiated in order to provide year round access by interested parties to mineral samples for assay and testing. Samples collected under this program are stored at the Stellarton regional office and plans to construct a permanent facility at the Core Library facility are underway.

A lot of time during this project was spent assisting industry to find additional reserves. Lafarge Canada Inc., Brookfield, Colchester County, undertook a large scale exploration program to find high calcium limestone deposits within economic transportation distance from their plant. A program consisting of field work, geophysical surveying, remote sensing and followup diamond drilling has resulted in Lafarge Canada Inc. bulk sampling limestone deposits at South Maitland and Manganese Mines. The limestone from these deposits is intended to be used to produce specialty petroleum cement and also to be blended with limestone from their existing quarry to extend its life. Ongoing exploration and development work continues on these and other promising properties.

Interest has been generated in other limestone deposits within the Province, in particular the larger George River Group carbonate deposits of Cape Breton. These multimillion tonne deposits are of interest to the large users such as cement companies, metallurgical interests, and environmental researchers into fluidized bed combustion power generation using Nova Scotia coal and limestone reserves.

Interest has been generated for development of the barite deposit at Scotsville, Inverness County, and interest continues in one of North America's premier celestite deposits at Lake Enon, Cape Breton County. An exploration program including drilling has spurred interest again in the Chegoggin Point, Yarmouth County, silica and garnet deposit. Andalusite deposits in Guysborough and Shelburne Counties have received renewed interest as possible ore sources for the alumina/refractory industries.

Ongoing research and assistance has been given to established mineral producers in the Province to find possible uses and markets for byproducts from their present operations. Topaz and muscovite are two byproducts from the East Kemptville tin mine which may have potential for a spinoff secondary industry.

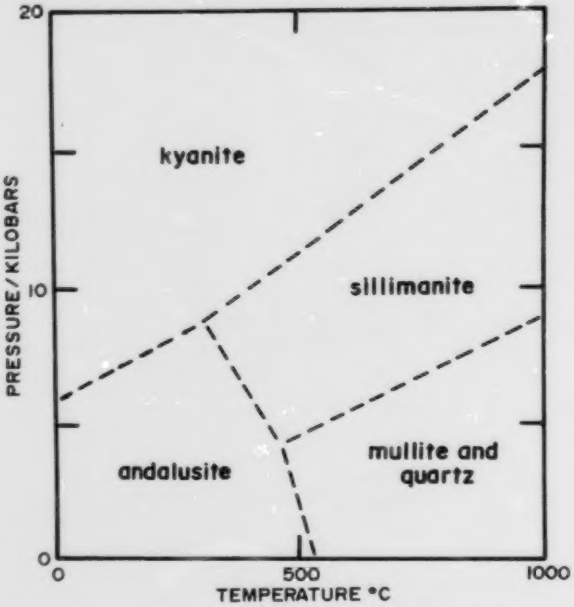
The Various Commodities Project has looked closely at most of the Province's lesser known industrial mineral commodities. Some important deposits have not received the attention they deserve and further investigations are warranted. Other deposits were not studied due to poor market conditions at this time and require work to encourage development when market conditions improve.

CHAPTER 2. ANDALUSITE AND RELATED MATERIALS

Andalusite, kyanite and sillimanite (AKS minerals), as well as synthetic mullite are anhydrous, aluminum silicate minerals that are similar in composition with the same chemical formula Al_2SiO_5. Closely related and included in the same group are topaz $Al_2SiO_4(F,OH)_2$, and staurolite $Al_2SiO_5Fe(OH)_2$ whose structures are very similar to kyanite. Sillimanite minerals are commercially rare. AKS minerals are primarily used in the refractory industry, where increasingly severe furnace conditions in iron and steel production have necessitated a move away from fireclay materials to those containing a high alumina content.

MINERALOGY

Although AKS minerals possess the same chemical composition, they exhibit different mineralogical properties which are summarized in Table 1. Such minerals generally occur in argillaceous or clay host rocks which have been metamorphosed. They also occur in alluvial concentrations derived from the weathering of primary deposits. Temperature and pressure gradients experienced during metamorphism determine which mineral species crystallize within the host rock. This relationship is illustrated by the Al_2SiO_5 phase diagram (Fig. 1). Andalusite forms under fairly high temperatures and low pressures and is typical of thermal aureoles and of rocks produced by regional metamorphism. Sillimanite forms under higher temperatures and pressures and commonly crystallizes in gneisses and hornfels characteristic of the innermost zones of thermal metamorphism. It may also form in schists associated with high grade regional metamorphism. Kyanite is characteristic of regionally metamorphosed rocks of intermediate grade formed under greater pressure.



from Industrial Minerals, 1985

Figure 1. Mineral phases within the Al_2SiO_5 system.

Other aluminium silicate minerals exist which have a similar composition to that of the above described minerals, but their occurrence is restricted. Natural mullite is extremely rare, occurring sometimes when aluminium-rich rocks have been subjected to extreme temperatures such as fragments of shale entrapped in a lava flow. It may be produced synthetically by sintering or fusion techniques involving mixes of kaolin, bauxite and silica. Topaz ($Al_2SiO_4(F,OH)_2$) is also a potential raw material for mullite production, but difficulties are

Table 1. The mineralogical characteristics of the AKS minerals.*

Mineral	Colour	Crystal System	Habit	Mohs Hardness	S.G.
Sillimanite	greyish white, grey to green	orthorhombic	fine needle-shaped particles	6-7	3.23
Andalusite	commonly pink also white, red, violet or green	orthorhombic	square prisms or massive radiating form	7.5	3.15
Kyanite	blue	triclinic	crystal aggregates with radiating or interlocking structure; also long bladed forms	5-7	3.6

*from Industrial Minerals, 1985.

encountered in the handling of fluorine gas which is drawn off when the material is calcined (Breen, 1986).

The mullite phase of these minerals possesses a high heat strength and a resistance to chemical and physical erosion; both properties are desirable in high temperature and chemically corrosive conditions. In refractory applications, the main performance criterion for alumina materials is the percentage of mullite formed within the material during firing. Andalusite, kyanite and sillimanite (AKS minerals) are all potential mullite producing minerals. When fired to a critical temperature (calcination), each mineral's chemistry breaks down to form the stable high temperature mullite phase with excess silica as shown below (Industrial Minerals, 1985):

$$3Al_2O_3 \cdot 2SiO_2 \quad \text{----->} \; 3Al_2O_3 \cdot SiO_2 + SiO_2$$
$$\text{(AKS minerals)} \; \text{----->} \; \text{(mullite)} + \text{(quartz)}$$

However, the decomposition temperature varies between the three allotropic forms (Table 2) and the process is further complicated by the rate of temperature increase, grain size and impurities present. Research indicates that mullitization begins on the surface of each grain and proceeds inwards so the period of heat treatment is also a factor to be considered for total mullitization and full density characteristics (Industrial Minerals, 1985).

Table 2. Mullite formation characteristics of the AKS minerals.*

Mineral	S.G.	Temperature of Mullitization	Volume Change on Conversion
Andalusite	3.15	1380°C-1400°C	+ 5%
Sillimanite	3.23	1550°C	+ 7%
Kyanite	3.60	1350°C-1380°C	+ 18%
Mullite	3.05	--	--

*from Industrial Minerals, 1985.

Apart from the temperature requirements, the chemistry of the raw materials is also important. For optimum mullite formation, the raw materials should possess an alumina content close to the theoretical content of mullite, 71.8% Al_2O_3. This factor is the major consideration for the use of andalusite, kyanite and sillimanite minerals as high-alumina mullite-forming refractories.

When the AKS minerals undergo mullitization, it is necessary to recognize that the temperature of transformation and the various associated physical phenomena differ appreciably between one mineral and another and confer distinct physical properties on the manufactured products. Kyanite is the most easily mullitized out of the three at temperatures of approximately 1350°-1380°C. This low temperature is advantageous with regard to energy costs. Kyanite is normally calcined before use because of its inherent expansion characteristics. Raw kyanite expands by 18% under firing although this is partially dependent upon the grain size and ambient temperature. Far from being a problem, this expansion can be controlled and used to advantage in offsetting the firing shrinkage of other raw materials such as clays. However, if the volume increase is not required, the kyanite has to be calcined before use since the mullitization process restricts any dimensional instability.

Andalusite changes at a slightly higher temperature of 1380°-1400°C, but because the accompanying volume increase is minimal, it can be fired in situ without prior calcination. Sillimanite is only changed conclusively at a much higher temperature, around 1550°C, and the associated volume change is also insignificant. Table 3 illustrates the temperatures and energy expenditures required when calcining various associated raw materials prior to their employment as refractories (Industrial Minerals, 1985).

Table 3. Comparison of the energy requirements of various refractory raw materials if calcining is necessary before employment.*

Material	Calcining Temperature °C	Energy for Calcination Btu x 10^6 per ton
Magnesite	1900-2000	6-42
Mullite	--	19
Bauxite 85-90%	1700-1800	13
Bauxite 70%	1700	9
Bauxitic Kaolin	1650-1700	8
Kaolin	1500-1650	7
Diaspore	--	5
Kyanite	1350-1380	4
Fireclay	1350	4
Sillimanite	Nil	Nil
Andalusite	Nil	Nil

*from Industrial Minerals, 1985.

It is the percentage of mullite that determines the refractory properties and hence the performance of the material. This phase gives a greater degree of resistance to creep deformation and slag attack, together with the ability to withstand high temperatures under load. Other desirable attributes include high thermal conductivity, a small coefficient of expansion, low porosity, and an increased resistance to spalling, reducing atmospheres and fluxing by volatile alkalies (Industrial Minerals, 1985).

Creep resistance is a measure of the ability of the brick to withstand high temperatures and loading over prolonged periods. This property can be impaired by the presence of fluxing impurities which lead to early softening of the brick. Andalusite bricks are superior because they contain less fluxing oxides (such as iron, titanium, calcium, magnesium, sodium and potassium) than high quality superduty fireclay bricks (Industrial Minerals, 1985).

In the AKS minerals, the mullite phase structure imparts a good thermal shock resistance which in turn makes them quite unaffected by sharp variations in temperature. This is primarily due to the low coefficient of expansion and high thermal conductivity of the material. Density and compactness contribute to the very low values of porosity which restrict the penetration of deleterious slags, gases and dusts. The inherent hardness of the AKS minerals is also a bonus in applications where corrosion and abrasion are a problem. This arises from the fact that the grains comprising the refractory have kept their original texture and have not, in excessive swelling, disturbed the intercrystalline and intergranular bindings (Industrial Minerals, 1985).

USES

An important characteristic in determining uses for the different AKS minerals is grain size. Kyanite is only available in fine grades down to 0.5 mm (35 mesh) because of the grinding required to separate the mineral during the froth flotation process. This small grain size restricts its use in brick manufacture and the 35-48 mesh range is used mainly in monolithic (nonvarying, uniform) applications such as castables, mouldables and ramming and gunning mixes. When used in such materials, it generally constitutes 10-40% of the mixture, the rest of which may be refractory clays or coarser grog material. The more finely ground kyanite material is often used in its uncalcinated state to offset the shrinkage of the host material. Such properties are needed by certain manufacturers of wall tiles, sanitary ware and other body-mix applications where shrinkage and cracking occur. In certain high grade refractories such as kiln furniture and precision investment casting applications, calcined kyanite is used bonded with a small amount of ball clay.

Kyanite usually has the advantage over andalusite with respect to iron contamination and the form in which it is present. Certain andalusites suffer from iron splatting. The iron is present in localized concentrations making the andalusite unacceptable in certain refractory applications. Kyanite, however, may possess similar quantities of iron impurity, but it tends to be present in a more discrete disseminated chemical form within the crystal. This most often permits it to be used in the ceramic, petrochemical and glass industries where iron contamination is stringently controlled. Approximately 95% of all kyanite produced is consumed by the refractories industry (60% for smelting and processing ferrous metals, 20% for nonferrous metals, and 15% for glass making and ceramics); the remaining 5% is used in various applications such as the manufacture of welding rod fluxes, insulators and brake shoes.

Andalusite used in refractories varies in grain size from 0.25-8 mm. In general the larger fractions are used in brick manufacture together with a carefully graded matrix fraction which, when fired, will give the greatest density and lowest porosity. It is the grain size distribution which is critical when producing the ideal physical characteristics of fired brick. In monolithic applications, although a fine grained material is required for gunning mixes and some mouldables, aggregate materials are needed for the concrete-like bodies of castable and ramming monolithics. Two potential monolithic markets are seen for such a coarse grained product: ramming materials used in iron runners, and low cement castables for use in steel ladles. Considerable development in the field of cements and binding agents is currently underway to develop more effective bonds. The rapid development of monolithics may eventually preclude the use of bricks in such applications as ladle linings, but, at present, brick manufacture remains the predominant consumer of andalusite. Steel producers are presently conducting trials on andalusite-based monolithic ladle linings as an alternative to sand/clay linings. One South African steel plant has increased its ladle lives from 25 to 60 heats using a 55% alumina andalusite brick compared with a super-duty firebrick. Changes in brick design and the introduction of thickness zoning in the ladle profile further increased ladle life to 75 heats.

In the cement industry there is a noticeable trend towards shorter rotary kilns with larger diameters. These have increased thermal efficiency and resulted in higher production capacities. This trend has also created more abrasive kiln environments, which are being successfully met by the use of high alumina refractories.

WORLD PRODUCERS

Andalusite reserves in the Republic of South Africa are reportedly sufficient to satisfy current world demand for the next 500 years. It is therefore not surprising to find that South Africa is the world's leading andalusite producer and net exporter with production in excess of 280 000 t in 1989 (McMichael, 1990). France and the United States are the next two leading producers with minor production occurring in India, Spain, Brazil and Australia. Although Canada possesses numerous AKS mineral deposits containing very large reserves, few have been subjected to detailed work and those investigated have been of low grade with poor recovery rates. To date no deposits of apparent economic value have been located. All Canadian AKS mineral requirements are met by imports chiefly from the United States.

NOVA SCOTIA POTENTIAL

The Cambro-Ordovician age rocks of the Meguma Group comprise 16 317 km^2 of the southern portion of mainland Nova Scotia. The porphyroblastic bearing metasedimentary rocks of the Meguma Group always occur associated with granitic intrusions throughout this portion of Nova Scotia. The particular chemical composition related to the sedimentation of these rocks, combined with large scale, orogenic forces consisting of folding with subsequent granite intrusion, are the main geological mechanisms responsible for the metamorphic history leading to the formation of the AKS minerals in certain areas of Nova Scotia.

There are several noted occurrences of AKS minerals throughout Nova Scotia. Areas with the most potential are the Dorts Cove, Black Point, Doughboy Point, Lundy and Donahue Lake areas, Guysborough County, Pubnico, Yarmouth County, and Jordan Falls area, Shelburne County.

Dorts Cove Area, Guysborough County

Other than exploration activity in the late 1950s, very little work has been conducted on the alumina bearing rocks of this area. In 1957-58, the Canadian Alumina Corporation Limited drilled a total of nine diamond-drill holes in the area of Dorts Cove, Guysborough County, (Fig. 2) to evaluate the quality and quantity of the aluminiferous slates between Delaney and Hyde Brooks (Rozovsky, 1958). A total of 1590.0 m (5216 ft) of diamond drilling was completed and analyses of the samples were carried out by the Nova Scotia Technical College, Halifax, and by the Technical Service Laboratories, Toronto. The result of this program outlined a 32 000 000 t block of aluminiferous slate, 30.5 m (100 ft) wide, 457.0 m (1500 ft) long and 90 m (297 ft) deep with an average content of 25% alumina (Rozovsky, 1958). During 1988 HECLA Mining conducted outcrop sampling and assaying, but have recently suspended operations (Tull et al., 1989).

Black Point, Guysborough County

In 1958, an exploration program of drilling and mapping was conducted by Cormier (1958) on the andalusite schist occurrence at Black Point, Guysborough County (Fig. 3). Seven shallow (<4 m) drillholes and three diamond-drill holes were drilled on the property in 1958 to help define the extent of the deposit on surface as well as at depth. The drilling results (Cormier, 1958) indicated a thinning of the zone along its strike from approximately 140 m at the coast to less than 60 m at the granite contact 425 m to the south. The andalusite bearing schist appears to be dipping 75°S. The andalusite occurs as elongated, prismatic crystals in a black, slaty schist. The andalusite crystals occasionally exceed 4 cm in length but, on average, they are from 1-2 cm in length. The best andalusite schist exposures containing about 20-25% andalusite crystals occur along the shore immediately south of Black Point for a distance of approximately 50 m from its contact with grey quartzite to the north. Small scattered outcrops of andalusite schist occur for an additional 90 m south along the

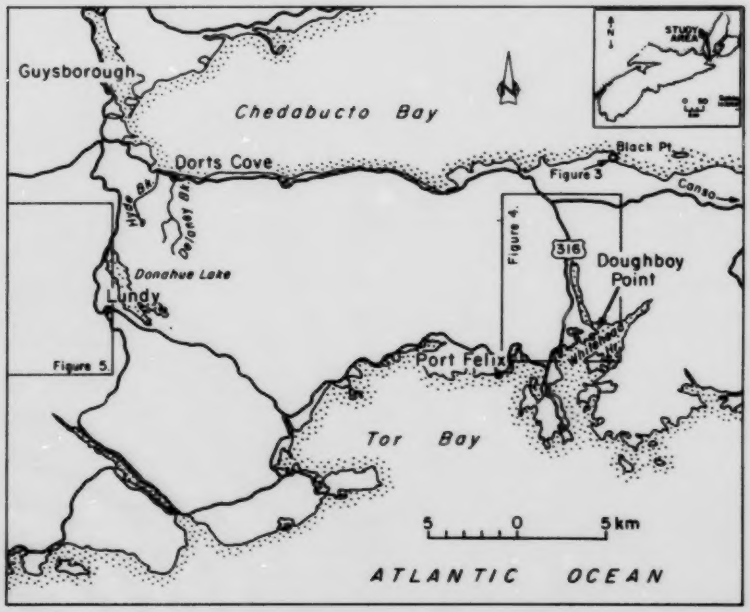


Figure 2. Location map showing Dorts Cove, Black Point, Doughboy Point, and Lundy, Guysborough County, andalusite/alumina occurrences.

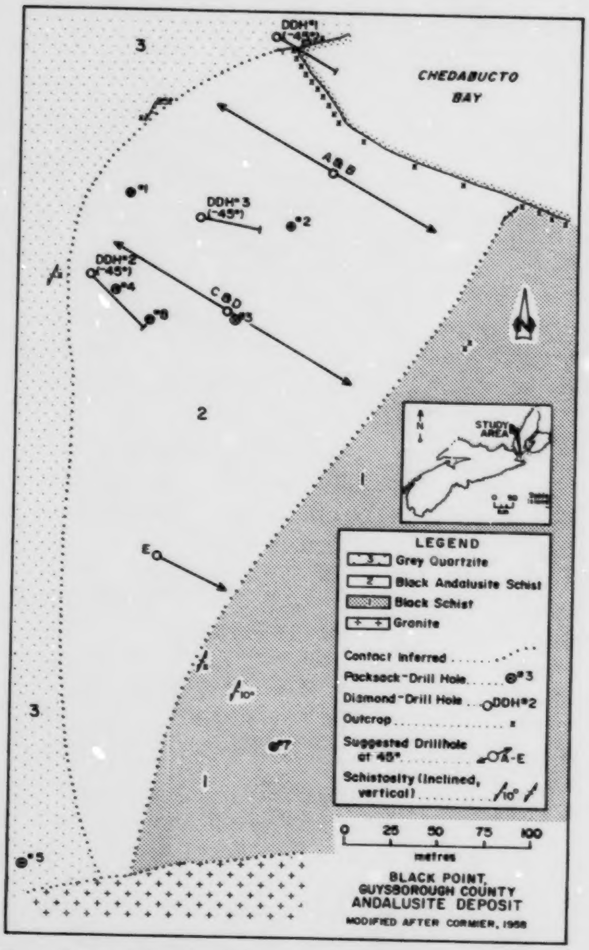

CHEDABUCTO BAY
DDH#1
DDH#3 (-45°)
DDH#2 (-45°)
A
B
C
D
E
STUDY AREA
LEGEND
3 Grey Quartzite
2 Black Andalusite Schist
1 Black Schist
+ + Granite
Contact inferred
Packsack-Drill Hole ●#3
Diamond-Drill Hole ○DDH#2
Outcrop
Suggested Drillhole at 45° A-E
Schistosity (inclined, vertical) 10°
0 25 50 75 100
metres
BLACK POINT, GUYSBOROUGH COUNTY ANDALUSITE DEPOSIT
MODIFIED AFTER CORMIER, 1958

Figure 3. Geological map of the Black Point area, Guysborough County, andalusite deposit showing diamond-drill hole locations and suggested locations for future drillholes. See Figure 2 for location.

shore. Inland no exposures of the andalusite bearing schist outcrop through the overburden, however, outcrops of quartzite, muscovite granite and nonandalusite bearing, black, slaty schist are present. Therefore, in conjunction with the drilling information, the andalusite bearing zone appears to extend inland approximately 425 m from the shore where it is cut off by a pronounced ridge of granite trending northeast-southwest. The andalusite zone is overlain to the northwest by grey quartzite and underlain to the southeast by nonandalusite bearing, black, slaty schist. Both the quartzite and black schist are cut off by the granite ridge.

The results of this work and others (Berkovich, 1958) indicated a distinct possibility for the presence of sizable bodies of commercial grade andalusite schist. The deposit's remote location on deep tidal water and the ease of mining via an open-pit mine also add to the attractiveness of developing this deposit.

Doughboy Point, Guysborough County

There exists a belt of andalusite bearing schists paralleling the regional folding that extends from two small islands off Doughboy Point in the upper northwestern arm of Whitehead Harbour past the northern side of Spears Lake to Port Felix and beyond to outcrop on the eastern shore of Tor Bay, Guysborough County (Figs. 2 and 4). The andalusite schist band lies within the Meguma Group and has been subjected to regional metamorphism due to the nearby Devonian granite intrusion. The best exposures of the andalusite schist are found on the shore at Doughboy Point where a thickness of 400 m is indicated. The beds strike 130° and the dip ranges from 75°SW to vertical. The andalusite schist consists mainly of fine grained muscovite flakes with minor amounts of biotite and chlorite containing large metacrysts of andalusite sometimes partly altered to muscovite. The exposure at Doughboy

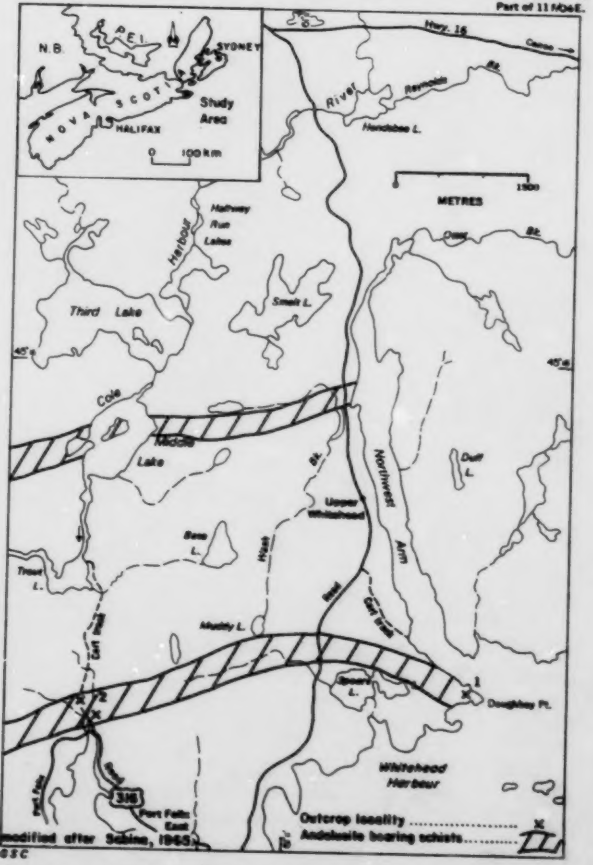

Part of 11 F/6E.
N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
Study Area
0 100 km
Hwy. 16
Canso
River
Reynolds Bk.
Hendsbee L.
METRES
1500
Halfway Run Lakes
Harbour
Third Lake
Smith L.
Bk.
45°
Cole
Middle Lake
Duff L.
Upper Whitehead
Northwest Arm
Bass L.
Trout L.
Muddy L.
Spears L.
1
2
Doughboy Pt.
Whitehead Harbour
316
Port Felix East
Outcrop locality X
Andalusite bearing schists
modified after Sabine, 1965
GSC

Figure 4. Andalusite occurrences, southeastern Nova Scotia: (1) Doughboy Point, and (2) Port Felix. See Figure 2 for location.

Point has andalusite crystals varying in size from 1-15 mm. The andalusite comprises 20-30% of the schist at this location, but additional work is required to determine if the crystals are indeed all andalusite; the degree of the metamorphism may have been higher forming additional types of AKS minerals. The alumina content is low for an andalusite ore and some staurolite crystals appear to be present in portions of the deposit.

The crystals are contained in a fine grained, muscovite-rich matrix with thin (1-2 cm), pink bands running randomly through it. These bands are comprised of very fine grained quartz and garnet devoid of andalusite. Magnetite, in small amounts (<1%), is scattered as inclusions in the other minerals.

A 2 t bulk sample of the andalusite ore was taken from the outcrop at Doughboy Point in 1988 and is presently stored at the Nova Scotia Department of Natural Resources' facility in Stellarton. Portions of this sample are available to any interested party for analytical work.

The andalusite and garnet bearing muscovite schist, exposed near Port Felix on the eastern side of the unnamed stream flowing into Port Felix Harbour approximately 100 m from Route 316 highway bridge, is similar to that exposed at Doughboy Point and is, in fact, the extension of the same schist belt. Magnetite is present as tiny, jet black specks and chlorite occurs as green, flaky streaks throughout the schist.

Lundy and Donahue Lake, Guysborough County

The Lundy deposit occurs in an andalusite schist exposed in a road cut along the Lundy-New Harbour Road and extends westward past Loon Lake to the western shore of the New Harbour River (Fig. 5). The andalusite occurs as opaque, dull black prisms averaging 1.2 cm long and 0.3 cm wide. Fine grained, massive patches of dull red garnet mixed with quartz are found in the schist. A sample collected by the author (1987) assayed 52.81% SiO_2 and 23.40% Al_2O_3.

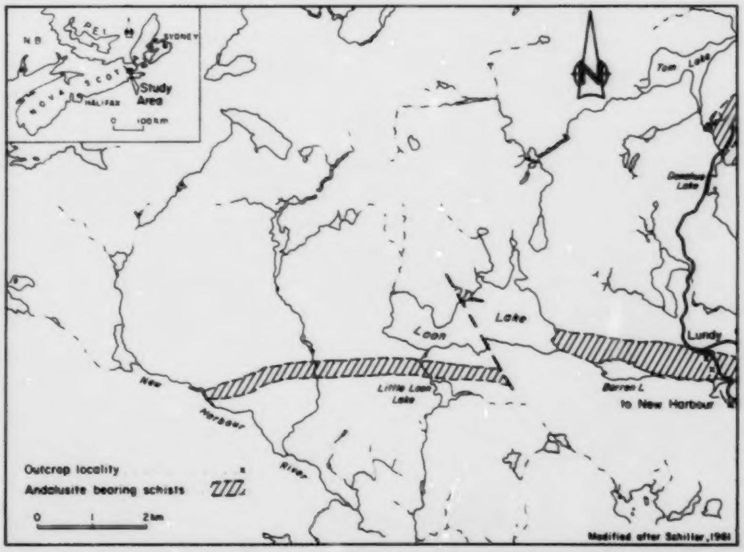
Andalusite in the Donahue Lake deposit occurs as pink to yellowish-brown, transparent, prismatic crystals averaging 4 cm long and 6 mm wide. The largest crystals observed measured 8 cm long and over 1 cm wide. The andalusite bearing slate is exposed in outcrop along the eastern side of the man made channel connecting Donahue and Tom Lakes (Fig. 5).

Pubnico, Yarmouth County, and Jordan Falls, Shelburne County

The highly contorted andalusite at Pubnico Point occurs in a thick sequence of layered schists of the Halifax Formation which is exposed in the core of a steeply plunging, upright syncline (Fig. 6). Exposures are limited and occur along the shoreline, roadcuts and small local aggregate quarries. Elongate andalusite crystals, up to 15 cm, make up 20-30% of the schists with a few local layers in the schists containing up to 50% andalusite crystals.

The andalusite crystals are impure and poikiloblastic, being composed of numerous thin inclusions of other minerals which the andalusite has overgrown. Thin section study of the andalusite crystals themselves reveals an andalusite content of 48.5-52%; quartz makes up 28-32.2%; biotite comprises 14-20%; muscovite makes up 0.5%; garnet 1-2%; and graphite 1.5-4% (Tull et al., 1989). The purest andalusite occurs in graphite schists near the bottom of the Halifax Formation where the crystals are up to 1.5 cm in length and are free of inclusions.

The andalusite bearing rocks which run north from Pubnico are generally of low quality, occurring in dark phyllites and fine grained garnet-biotite schists. Only a few exposures have andalusite crystals comprising over 10% of the rock and therefore this area does not have the potential of the Lower West Pubnico deposit.



Modified after Schiller,1981

Figure 5. Andalusite occurrences, Lundy and Donahue Lake, Guysborough County. See Figure 2 for location.

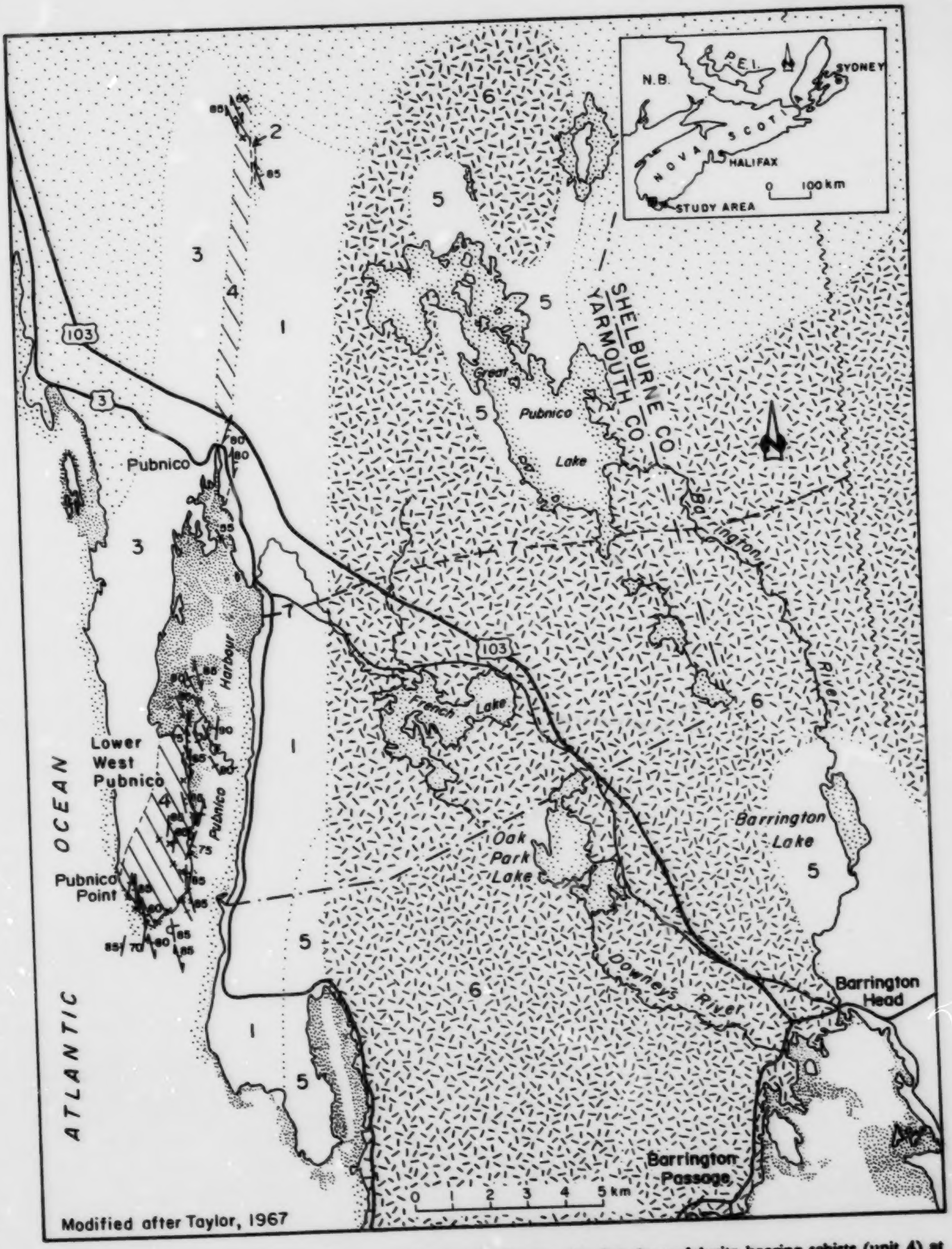

N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
0 100 km
STUDY AREA
6
5
2
3
4
1
5
SHELBURNE CO.
YARMOUTH CO.
Great Pubnico Lake
103
3
Pubnico
3
7
7
103
Harbour
Pubnico
Lower West Pubnico
4
Pubnico Point
OCEAN
ATLANTIC
1
French Lake
Barrington River
6
Barrington Lake
5
Oak Park Lake
5
6
Downeys River
Barrington Head
1
5
Barrington Passage
0 1 2 3 4 5 km
Modified after Taylor, 1967

Figure 6. Geological map of the Pubnico area, Yarmouth County, showing the andalusite bearing schists (unit 4) at Pubnico Point. See p. 12 for legend and location.

LEGEND

DEVONIAN OR LATER

7 Quartz diabase

DEVONIAN

6 Granite

ORDOVICIAN AND EARLIER

Lower Ordovician and (?) Earlier

MEGUMA GROUP (1-5)

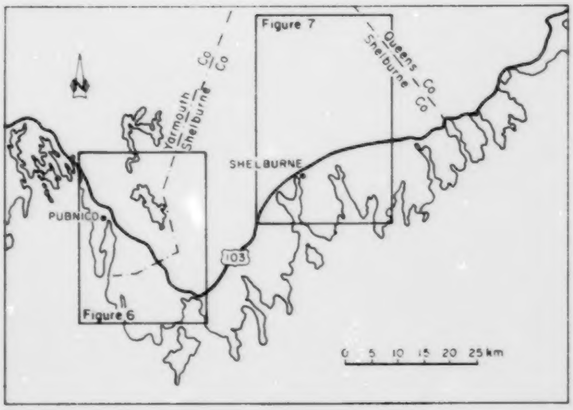
3 4 *Halifax Formation*

3. Slate, siltstone and minor argillite.
4. Metamorphosed equivalents of 3. Staurolite schist, andalusite schist, staurolite-cordierite schist, staurolite-andalusite schist.

1 2 *Goldenville Formation*

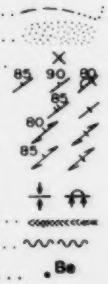
1. Greywacke
2. Metamorphosed equivalents of Unit 1.

5 Metamorphosed equivalents of Units 1 and 3.



SYMBOLS

Geological contact (approximate, assumed)
Drift covered area
Rock outcrop
Bedding, tops known (inclined, vertical, overturned)
Bedding, tops unknown (inclined, vertical)
Cleavage (inclined, vertical)
Schistosity, gneissosity (inclined, vertical)
Syncline (approximate trace of axial surface; overturned)
Esker
Fault (approximate)
Beryllium occurrence



modified after Taylor, 1967

Figure 6. Continued. Legend, symbols and location map for Figures 6 and 7.

The Halifax Formation is exposed along roadcuts between Shelburne and Jordan Falls (Fig. 7). The Halifax Formation schists are exposed in a limb of a regional northward plunging syncline which is upright and open. Massive metagreywackes of the Goldenville Formation and the edge of the Shelburne granite pluton surround the staurolite, cordierite, andalusite bearing Halifax Formation schists.

Most of the schists contain andalusite crystals comprising <10% of the rock with a few areas containing 15-17% andalusite crystals. The andalusite crystals are similar to those at Lower West Pubnico, both containing minute inclusions of quartz, mica and graphite.

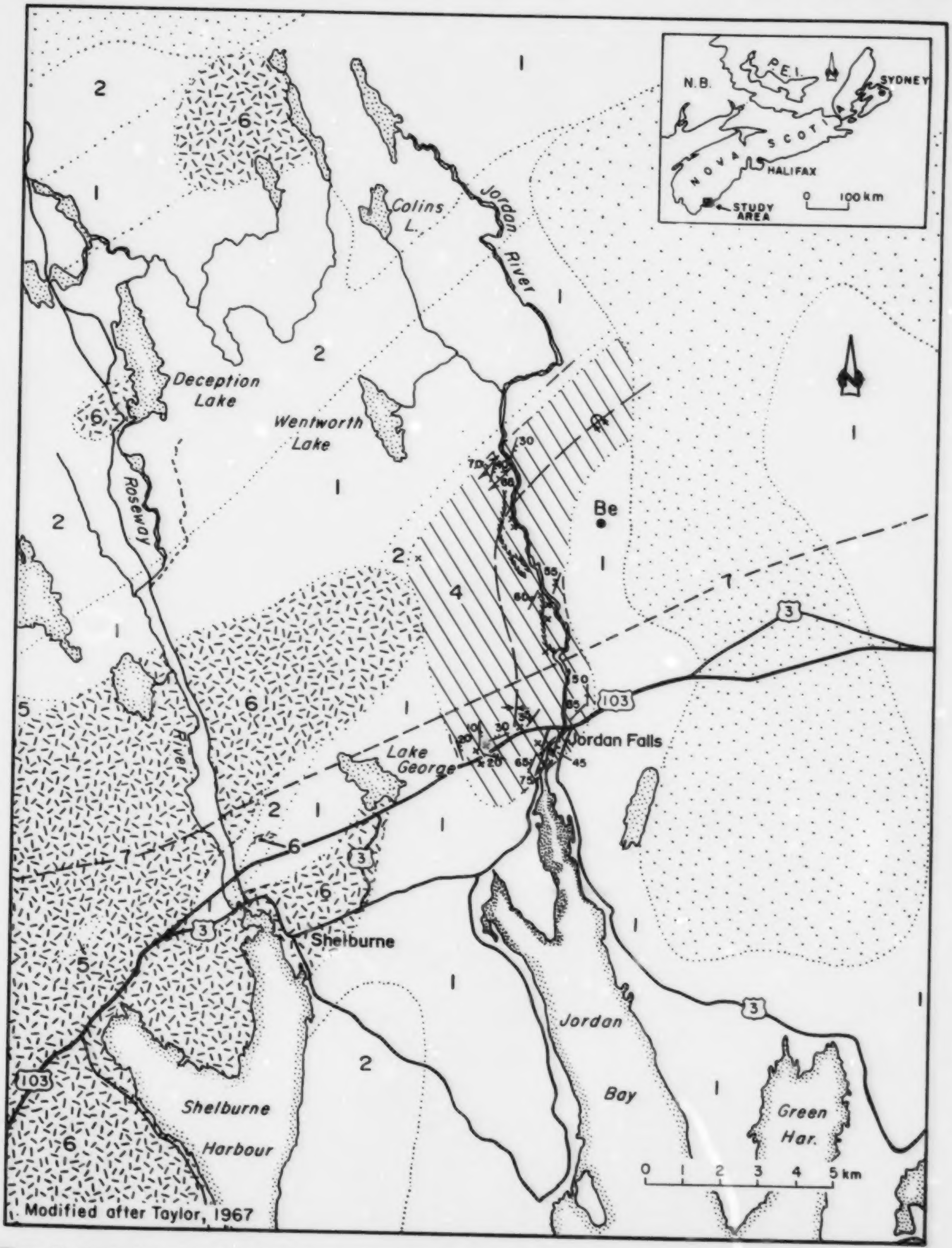

N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
STUDY AREA
0 100 km
Colins L.
Jordan River
Deception Lake
Wentworth Lake
Roseway River
Be
Lake George
Jordan Falls
Shelburne
Jordan Bay
Green Har.
Shelburne Harbour
103
3
0 1 2 3 4 5 km
1
2
4
5
6
7
Modified after Taylor, 1967

Figure 7. Geological map of the Shelburne and Jordan Falls area, Shelburne County, showing the andalusite, staurolite, cordierite schist (unit 4). See Figure 6 for legend and location.

CHAPTER 3. BARITE

Barite is a member of the anhydrous sulphate series of minerals with the chemical formula $BaSO_4$. The crystal system is orthorhombic dipyramidal as evident in a variety of habits, the most common being thin to thick tabular and also prismatic and elongated. Generally barite occurs in a massive form with grain size varying from cryptocrystalline to very coarse.

Barite has a specific gravity of 4.5, is a brittle mineral with a hardness ranging from 3-3.5 on the Mohs scale. Cleavage is perfect along (001) and (210). Barite is colourless to white. It is also yellow, brown, pink, reddish, grey greenish or blue because of impurities within. Before the blow pipe, barite decrepitates and fuses with difficulty, giving a yellowish green flame (Felderhof, 1978).

USES

Eighty per cent of the market for barite is in the oil and gas exploration and development industry. Barite is an excellent drilling mud additive because it is soft and easily crushed and milled. Barite is virtually chemically inert so it does not react with other drilling substances. The high specific gravity of barite is sufficient to contain downhole pressures that may be encountered when drilling over pressure zones such as those evident around Sable Island, Nova Scotia. The American Petroleum Institute (API) specifications for drilling mud barite are given in Table 4.

Table 4. Specifications for various barite uses.[*]

General specifications for A.P.I. drill-mud barytes

Specific gravity	4.2 min
$BaSO_4$	92% min
Soluble alkaline earth content, as calcium	250 ppm max
Particle size	95%-45μm (325 mesh)

Source: American Petroleum Specification 13A for Oil Well Drilling - Fluid Materials, 1981

General specifications for pharmaceutical-grade barytes

$BaSO_4$	97.5% min
LOI	<2% (600°C)
Heavy metals (as Pb)	0.001% max
Sulphides	<0.01 ppm
Arsenic	<0.01 ppm
Particle size	90%-20μm
Colour	white or near white
Odour	odourless

General specifications for filler applications

$BaSO_4$	95% min
Particle size	95%-45μm
Colour	colour specifications vary depending on application, usually a near-white product is required

General specifications of glass-grade barytes

$BaSO_4$	95% min
SiO_2	1.5% max
Iron (as Fe_2O_3)	0.15% max
Al_2O_3	0.15% max
Particle size	100%-85μm with less than 5%-150μm fines

General specifications for barytes as heavy aggregate

$BaSO_4$	95% min
Particle size	gravel size

Specifications for barium chemicals manufacture

$BaSO_4$ (lump material)	92-96% min
$BaSO_4$ (flotation concentrate)	96-98% min
Fe_2O_3	1.0% max
$SrSO_4$	1.0% max
CaF_2	0.5% max
Particle size	-5.0 + 0.5 mm

General specifications for paint-grade barytes

Particle size	99.98% passing 37μm (400 mesh)
Hegman number	6.5
Brightness (green filter)	81%
Oil absorption	5 kg/45 kg
$BaSO_4$	95% min
Iron content	0.05% max
Water soluble compounds	0.2% max
Foreign matter	2.0% max
Moisture	0.5%
pH	6.4

Source: American Society for Testing and Materials, ASTM D-1366 (size), D-281 (oil absorption), D-280 (moisture), D-1208 (water insoluble), D-1208 (pH).

[*] from Andrews and Collings, 1990.

Other than the principal market of the oil and gas industry, barite has thousands of specific industrial applications. Filler and extender grade barite is used in the manufacture of paint, plastics, rubber, adhesives and sealants. Other applications include glass making, ceramics and pharmaceuticals. In the filler industry the inherent characteristics of barite, which include high specific gravity, radiation shielding, and sound deadening qualities, are particularly desired.

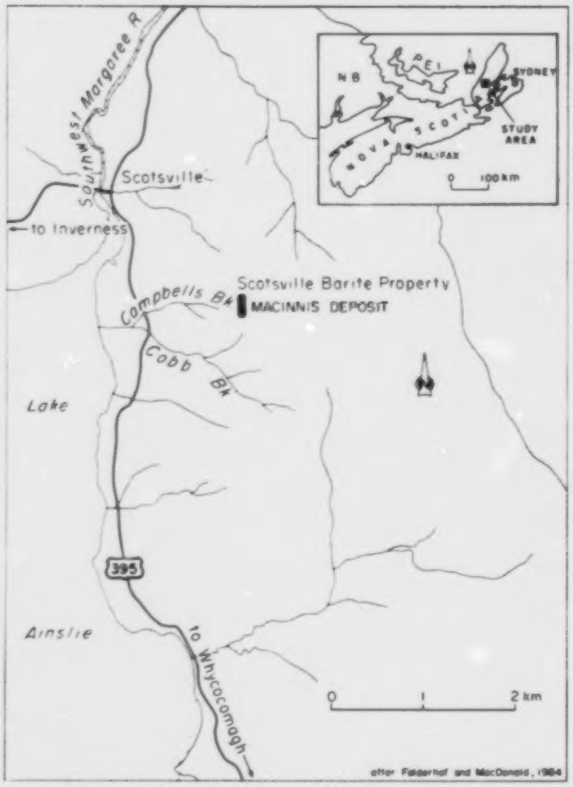
Specifications for the different applications of barite vary and often vary from one manufacturer to another. The price paid depends on grade, brightness, sizing and demand. Current prices are available each month in a number of journals including *Industrial Minerals* and the *Engineering and Mining Journal*.

NOVA SCOTIA POTENTIAL

A very thorough and complete report on over 130 known barite occurrences within Nova Scotia is available (Felderhof, 1978). Included in this publication are locations of all known occurrences with a brief description and chemical analysis of each when available. Duplication of this work will not be made here, but a few selected Provincial barite deposits with excellent potential for development will be discussed.

Scotsville, Inverness County

Exploration work on the Scotsville property, MacInnis deposit, (Fig. 8) between 1982 and 1984 led to the granting of a mining licence and the establishment of an operation to mine barite initially aimed at the then thriving East Coast offshore oil and gas exploration industry. The MacInnis barite deposit occurs as a continuous vein at least 200 m long, infilling the fissure along the angular unconformity separating the underlying Precambrian George River Group metasedimentary rock and the overlying Horton Group sedimentary rock of Lower Carboniferous age. Devonian granite intrusives occur as well along this unconformity offsetting the barite vein in places. The George River Group rocks strike north to northeast and dip steeply east to vertical. The Horton Group rocks strike north and dip approximately 30° east. The barite vein strikes north at 357° and dips 50-60° east at surface and shallows to 35-40° east at depth. The Horton Group sedimentary rocks are broken and badly faulted, but have caused only minimal displacement of the barite vein. Total reserves of 101 510 t grading 60.76% $BaSO_4$ were delineated on the MacInnis vein by a diamond drilling program (Felderhof and MacDonald, 1984). Metallurgical testing of the ore proved it could easily meet API specifications by crushing to -0.63 cm (-1/4") and jigging. The high brightness of the white barite ore and results of initial metallurgical testing indicated this ore can economically meet the specifications of a filler grade barite and portions of the deposit can supply the pharmaceutical market (Stone, personal communication, 1986). The Scotsville barite deposit is high grade, has proven reserves in situ, infrastructure established, and the potential for additional reserves downdip and adjacent to the MacInnis vein is excellent. It should be further explored by diamond drilling.



after Felderhof and MacDonald, 1984

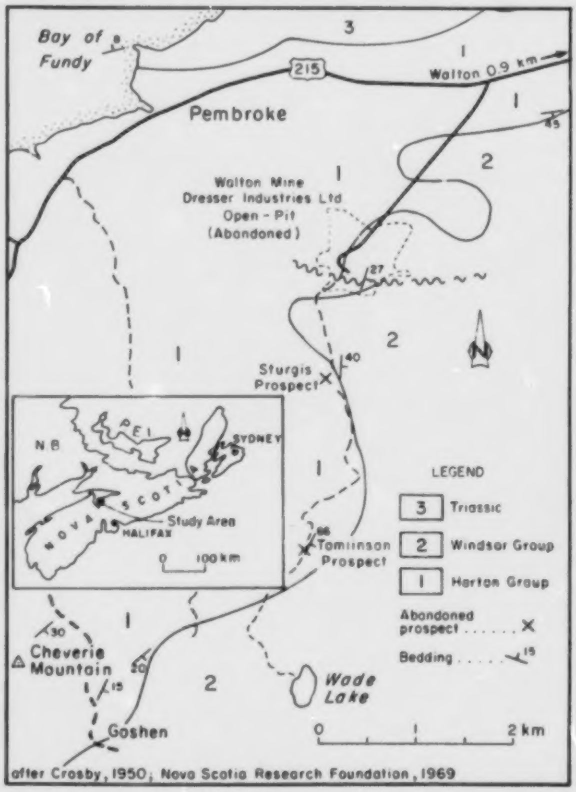
Figure 8. Location map showing Scotsville barite deposit, Inverness County.

Walton, Hants County

The barite deposit near Walton, Hants County, was the site of Canada's largest barite mine. During the 38 years of production, the Walton Mine produced 4.3 Mt of barite which was mostly shipped to the United States and the Caribbean to be used as a weighting additive to drilling muds. A small amount of chemical and filler grade barite was mined and sent to markets in Central Canada. An estimated 900 000 t of barite remains underground at Walton, and additional reserves could be recovered from the old mine tailings.

In addition, there exists the possibility of other ore bodies to the southwest of the main ore body at Walton along the area of the Horton Group and Windsor Group contact (Fig. 9). Based on the same structural controls encountered at the Walton Mine, a promising exploration target would be any slight change in strike along the line of strike where an area of tension might occur offering the plumbing necessary for barite and sulphide mineralization. Using the available data there appear to be two general areas of compression and two general areas of tension from the Town of Walton southwestward to the area south of Goshen. The two areas of regional tension are from Walton Mine through to the Sturgis prospect and from the Tomlinson prospect through to Goshen. The area immediately south of the Walton Mine containing the proposed Horton Thrust (Crosby, 1950) may contain a normal fault (downside to the east) and a large scale roll over to the west, at depth. This area should be explored by diamond-drill holes to a depth of 460.0 m.

The area between Tomlinson and Goshen is encouraging because of the known major change in the contact strike in the area. Gravity work by the Nova Scotia Research Foundation (1969) in this area indicated the presence of a drag fold which could provide the structure to host mineralization. Barite mineralization occurs throughout this area. Further exploration by drilling is recommended.



after Crosby, 1950; Nova Scotia Research Foundation, 1969

Figure 9. Location map showing site of former Dresser Industries Ltd. barite, lead, zinc, silver mine near Walton, Hants County. Similar mineralization and structural geology is apparent at Sturgis and Tomlinson which are excellent exploration targets.

East Lake Ainslie, Inverness County

A promising barite-fluorite deposit has been defined at East Lake Ainslie, Inverness County (Fig. 10; Table 5). This property consists of nine barite-fluorite veins with estimated reserves of 4.1 Mt, averaging 33.4% barite and 17.4% fluorite (Zurowski, 1972). The majority of the deposits are contained in fault cavities and subsidiary tension fractures and shears mostly in volcanics of the Fisset Brook Formation. One vein occurs along a fault contact between Fisset Brook Formation rhyolitic tuff and Horton Group sedimentary rocks (Zurowski, 1972).

The best potential for development exists in two deposits: the MacMillan vein and the Upper Johnson vein. The MacMillan vein (vein 8) strikes east-west and dips 65-70° to the south. Reserves are estimated at 2.6 Mt, averaging 27.8% barite, and 19% fluorite (Zurowski, 1972). The Upper Johnson vein (vein 4) strikes S85°W and dips 85° north to vertical. Reserves are calculated at 960 000 t of 45% barite, and 17% fluorite. Metallurgical studies and pilot plot testing concluded that API drilling mud grade barite and metallurgical grade and acid grade fluorspar can be produced from these deposits (Zurowski, 1972). Further testing is ongoing to determine if the barite is suitable for the manufacture of specialty barite compounds.

Pine Brook, Richmond County

The Pine Brook, Richmond County, deposit (Fig. 11) was mined briefly in 1984 by Novex Mining and Exploration Co. Ltd. to provide barite for the then flourishing East Coast offshore oil and gas drilling activities. An estimated 5700 t of API mud grade barite was produced from the Pine Brook deposit using the former Kaiser floatation mill at Loch Lomond (Andrews and Collings, 1990).

The Pine Brook barite deposit is a replacement deposit with barite replacing limestone. The barite bed is <1 m thick and is open downdip. It appears to be stratigraphically controlled having preferentially replaced only one limestone bed of the Windsor Group at this locality. Additional work in the form of a systematic diamond drilling program is recommended to better define the extent and quality of the barite deposit.

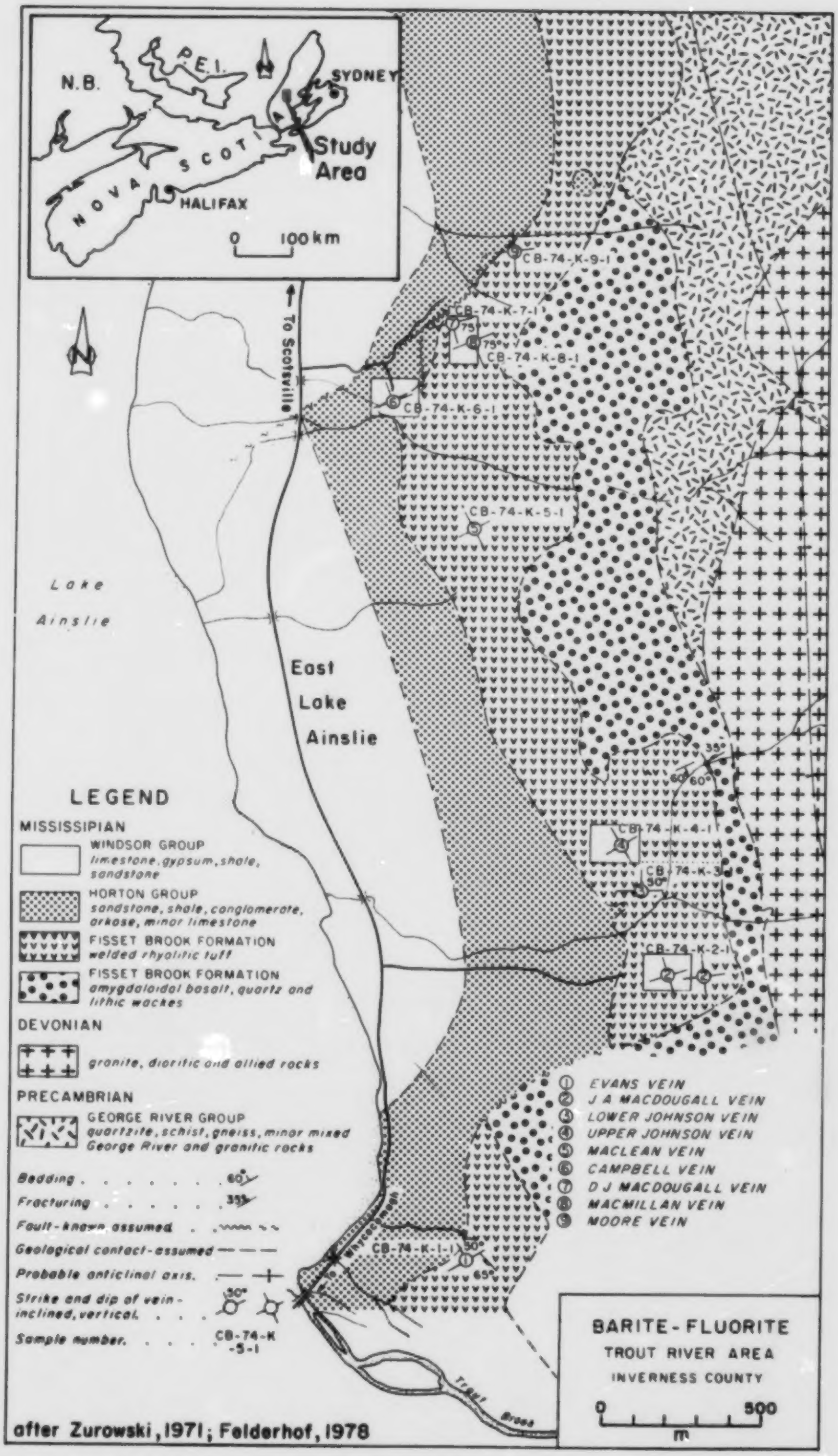

N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
Study Area
HALIFAX
0 100km
To Scotsville
CB-74-K-9-I
CB-74-K-7-I
CB-74-K-8-I
CB-74-K-6-I
CB-74-K-5-I
Lake Ainslie
East Lake Ainslie
CB-74-K-4-I
CB-74-K-3
CB-74-K-2-I
CB-74-K-1-I
LEGEND
MISSISSIPIAN
WINDSOR GROUP limestone, gypsum, shale, sandstone
HORTON GROUP sandstone, shale, conglomerate, arkose, minor limestone
FISSET BROOK FORMATION welded rhyolitic tuff
FISSET BROOK FORMATION amygdaloidal basalt, quartz and lithic wackes
DEVONIAN
granite, dioritic and allied rocks
PRECAMBRIAN
GEORGE RIVER GROUP quartzite, schist, gneiss, minor mixed George River and granitic rocks
Bedding 60°
Fracturing 35°
Fault-known, assumed
Geological contact-assumed
Probable anticlinal axis
Strike and dip of vein-inclined, vertical 50°
Sample number CB-74-K-5-I
① EVANS VEIN
② J A MACDOUGALL VEIN
③ LOWER JOHNSON VEIN
④ UPPER JOHNSON VEIN
⑤ MACLEAN VEIN
⑥ CAMPBELL VEIN
⑦ D J MACDOUGALL VEIN
⑧ MACMILLAN VEIN
⑨ MOORE VEIN
Trout Brook
BARITE-FLUORITE
TROUT RIVER AREA
INVERNESS COUNTY
0 500 m
after Zurowski, 1971; Felderhof, 1978

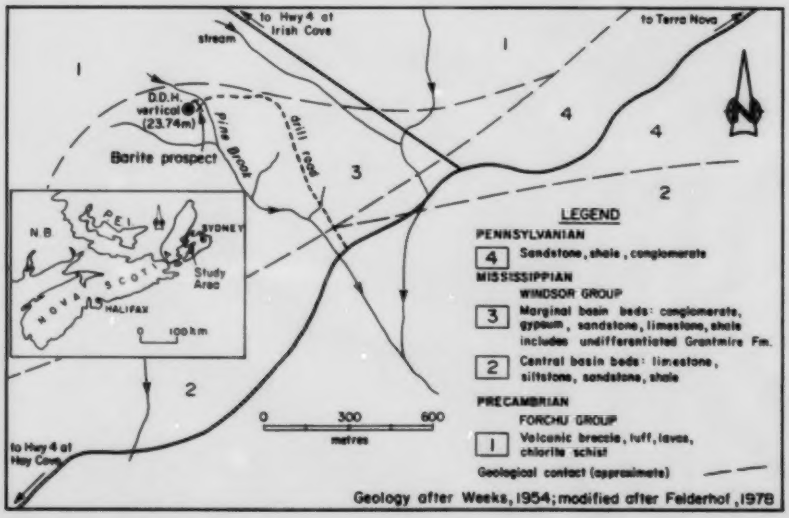
Figure 10. Location and geology map showing barite, fluorite deposit at East Lake Ainslie, Inverness County.

Table 5. Analysis of samples collected in 1974 from East Lake Ainslie, Inverness County, barite, fluorite occurrences.*

Sample	Parts Per Million		
No.	Copper	Lead	Zinc
CB-74-K-1-1	20	10	20
CB-74-K-2-1	80	10	20
CB-74-K-3-1	110	10	20
CB-74-K-4-1	160	30	20
CB-74-K-5-1	80	10	15
CB-74-K-6-1	80	30	30
CB-74-K-7-1	40	10	50
CB-74-K-8-1	80	30	30
CB-74-K-9-1	10	10	20

Sample	Percentage									
No.	Fluorine	BaO	SrO	Silica	Fe_2O_3 (Total)	MnO	Al_2O_3	CaO	LOI	Total
CB-74-K-1-1	2.94	61.13	0.32	<0.50	0.12	0.01	0.11	3.50	<0.20	99.77
CB-74-K-2-1	0.90	62.81	1.18	0.36	0.14	0.01	0.06	1.26	0.81	100.88
CB-74-K-3-1	10.80	50.02	1.02	<0.50	0.11	0.01	0.06	13.90	-	98.79
CB-74-K-4-1	5.40	53.00	0.90	0.38	0.13	0.01	0.11	9.80	1.09	96.94
CB-74-K-5-1	1.60	60.12	1.24	0.09	0.17	0.03	0.17	3.01	3.00	101.11
CB-74-K-6-1	18.32	31.04	0.80	0.06	0.11	0.04	0.10	32.20	-	91.80
CB-74-K-7-1	2.50	60.48	1.17	<0.50	0.16	0.02	0.15	1.01	3.05	100.47
CB-74-K-8-1	12.20	48.57	1.24	0.20	0.30	0.01	1.22	14.98	0.76	100.66
CB-74-K-9-1	0.37	63.47	1.40	0.77	0.10	0.01	0.38	0.20	<0.20	100.96

*modified after Felderhof, 1978.

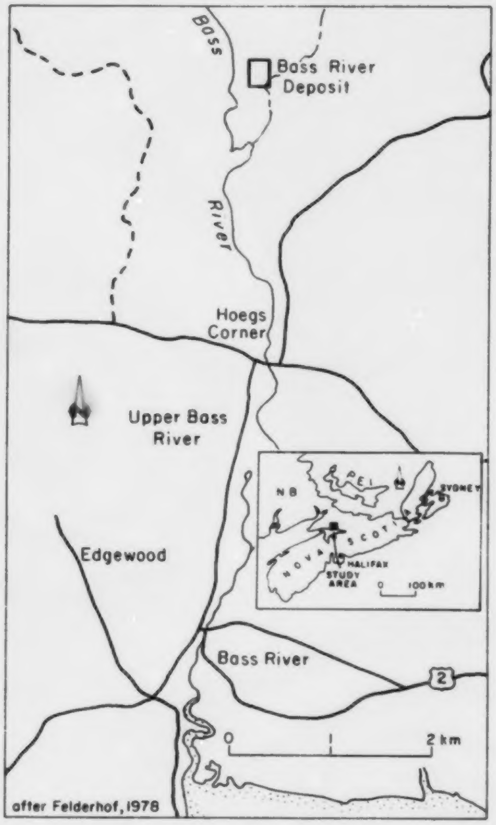

to Hwy 4 at Irish Cove
to Terra Nova
stream
1
1
D.D.H. vertical (23.74m)
Pine Brook
drill road
Barite prospect
3
4
4
2
2
N.B
P.E.I
SYDNEY
NOVA SCOTIA
Study Area
HALIFAX
0 100 km
0 300 600
metres
to Hwy 4 at Hay Cove
LEGEND
PENNSYLVANIAN
4 Sandstone, shale, conglomerate
MISSISSIPPIAN
WINDSOR GROUP
3 Marginal basin beds: conglomerate, gypsum, sandstone, limestone, shale includes undifferentiated Grantmire Fm.
2 Central basin beds: limestone, siltstone, sandstone, shale
PRECAMBRIAN
FORCHU GROUP
1 Volcanic breccia, tuff, lavas, chlorite schist
Geological contact (approximate)

Geology after Weeks, 1954; modified after Felderhof, 1978

Figure 11. Location map showing barite deposit at Pine Brook, Richmond County.

Bass River, Colchester County

A barite deposit at Bass River, Colchester County, (Fig. 12) was developed in 1985 by Dresser Industries to produce API oil well grade barite. Approximately 3500 t of barite were extracted from the deposit and used in oil well drilling. Further diamond drilling to define additional reserves was unsuccessful and it appears that most of the economically retrievable ore has been mined (Dresser Industries, personal communication).


Bass
Bass River Deposit
River
Hoegs Corner
Upper Bass River
Edgewood
Bass River
2
0 1 2 km
NB
PEI
SYDNEY
NOVA SCOTIA
HALIFAX
STUDY AREA
0 100 km

after Felderhof, 1978

Figure 12. Location map showing barite deposit at Bass River, Colchester County.

CHAPTER 4. BERYLLIUM

Beryl and bertrandite are the only commercial sources of beryllium. Beryl belongs to the cyclosilicate group. Its formula is $Be_3Al_2Si_6O_{18}$. Beryl has a hardness of 8, a density of 2.65-2.85, a white streak and a vitreous lustre. It is commonly pale green in colour, but may also be white or yellow. It can be translucent or transparent. The transparent gem quality varieties of beryl are dependent on the following colours: dark or light green (emerald), bluish green (aquamarine), yellow (heliodor) and pink (morganite). Beryl commonly occurs in granite pegmatites and occasionally within druses in granite. Fine gem quality emeralds occur in cavities in bituminous limestones in Colombia. Emeralds have also been found in mica schists (usually comprising the wallrock of pegmatite veins).

USES

Beryllium is used as an alloy and metal in nuclear reactors and aerospace applications; as an alloy and oxide in electrical equipment and components; and as compounds and metals for lesser specialized applications. Although high priced, beryllium is unmatched particularly in applications which require its light weight, high strength and high thermal conductivity.

WORLD SUPPLY AND PRODUCTION

The United States is the world's largest mine producer of beryllium minerals with the U.S.S.R., Brazil and China the other principal producers (Kramer, 1986a) (Table 6).

HECLA Mining of Canada Ltd. is completing technical and marketing feasibility studies with Highwood Resources Ltd. on a beryllium-rare earths property at Thor Lake, Northwest Territories. Reserves at this deposit are estimated to be 1.8 Mt averaging 0.85% beryllium oxide (Kramer, 1986a).

Total domestic beryllium bearing resources in market economy countries are estimated to be 120 Mt of ore, containing over 36 000 t of beryllium metal.

At the end of 1986, the price range for beryl ore quoted in *Metals Week* was $78-85 (U.S. dollars) per short ton unit (20 pounds) of contained beryllium oxide. The following prices for beryllium materials were quoted in *American Metal Market*, in United States dollars per pound, except for beryllium-copper master alloy, which was given in dollars per pound of contained beryllium (Table 7).

Table 6. World production of beryl by country.[1*]

Country	1982	1983	1984	[p]1985	[e]1986
Argentina	7	26	28	[e]17	35
Brazil	1251	1039	1551	967	1050
Madagascar[2]	75	(3)	51	[e]55	55
Mozambique	9	7	8	[e]7	7
Portugal	13	3	11	[e]11	13
Rwanda	76	35	49	30	30
South Africa, Republic of	64	23	1	6	6
U.S.S.R.[3]	2000	2100	2100	2100	2100
United States[4] (mine shipments)	5451	6665	6030	5738	[5]6533
Zimbabwe	57	52	21	42	45
Total	9003	9950	9850	8973	9874

[e] Estimated. [p] Preliminary.

[1] In addition to the countries listed, China produced beryl, and Bolivia and Namibia may also have produced beryl, but available information is inadequate to formulate reliable estimates of production. Nepal reports producing small amounts. Table includes data available through Apr. 14, 1987.

[2] Includes ornamental and industrial products.

[3] Less than 1/2 unit.

[4] Includes bertrandite ore, calculated as equivalent to beryl containing 11% BeO.

[5] Reported figure.

[*] from Kramer, 1986a.

Table 7. Price list for beryllium, 1986.[*]

Vacuum cast ingot 97% pure	US$ 225
Metal powder, in 5000-pound lots and 97% pure	196
Beryllium-copper master alloy	152
Beryllium-copper casting alloy	5.40-6.00
Beryllium-copper in rod bar, wire	8.50
Beryllium-copper in strip	7.65
Beryllium-aluminum alloy, in 100 000-pound lots	248
Beryllium oxide powder	55.70

[*] from Kramer, 1986a.

NOVA SCOTIA POTENTIAL

The pegmatites which cut Devonian granites and Ordovician quartzites in southwestern Nova Scotia host the occurrences of beryllium which have the best potential for development. These pegmatites are concordant with the regional foliation of the country rock and vary in width from a few centimetres to over 30 m and generally extend for several hundred metres in length. The minerals identified in the pegmatites are quartz, plagioclase, feldspar, muscovite, biotite, perthite, garnet, tourmaline and beryl (Oldale, 1959).

Many of the pegmatites are homogeneous bodies of uniform composition and texture; in others, a border zone, wall zone and core characterized by certain mineral assemblages can be identified (Oldale, 1959). The zoned pegmatites appear to be the most important hosts for beryl. The beryl is generally found associated with pods and lens-like masses of quartz and perthite in the central part of the zoned pegmatites. Beryl is also associated with quartz, perthite and mica filling crossfractures in the pegmatites and in pegmatite quartz veins (Oldale, 1959).

Numerous pegmatitic beryl occurrences are found associated with the Devonian biotite-muscovite granite in the Port Mouton, Queens County, and Shelburne, Shelburne County districts. Some beryllium is found in pegmatite-like deposits of the New Ross, Lunenburg County district associated with Devonian muscovite granite.

The deposits with the best potential for development occur at Port Mouton Island, New Building Cove, Sandy Bay and Hunts Point in the Port Mouton district, Queens County (Fig. 13); in Morely's pegmatite at New Ross, Lunenburg County (Fig. 14); and at the Jordan River, Shelburne County, prospect 4 km north of Highway 103 at Jordan Falls (Fig. 7).

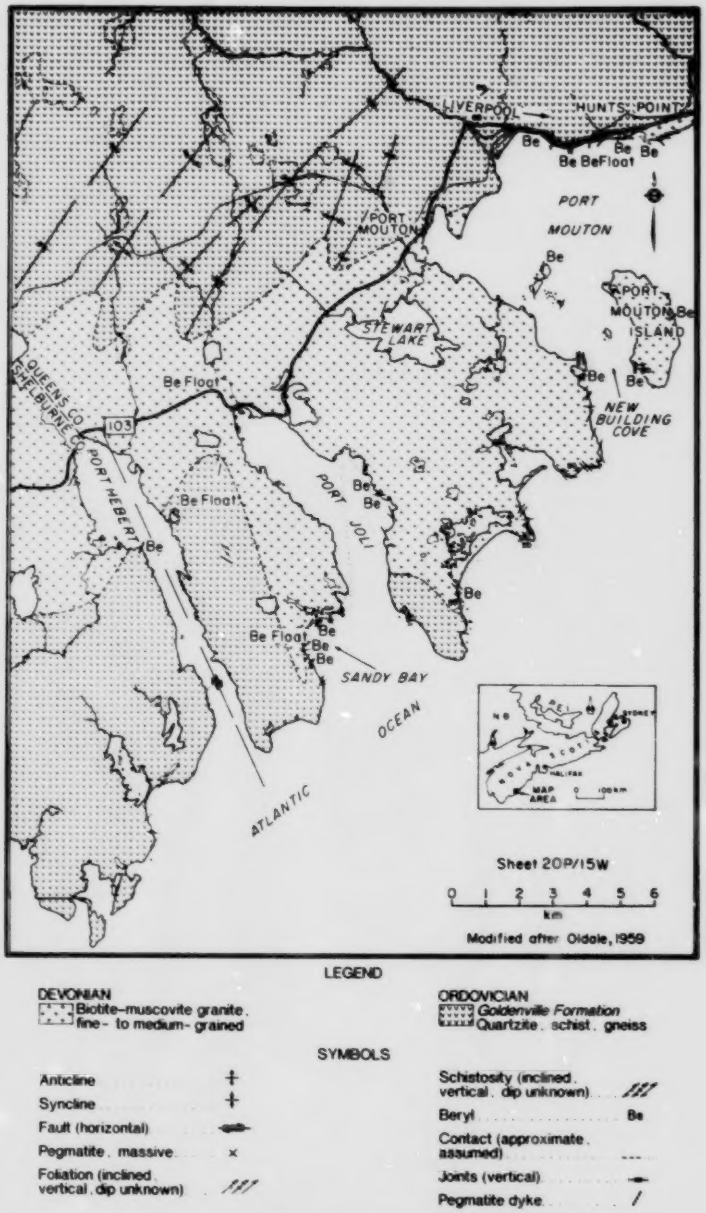

LIVERPOOL
HUNTS POINT
Be
Be BeFloat
PORT MOUTON
PORT MOUTON
PORT MOUTON ISLAND
STEWART LAKE
NEW BUILDING COVE
Be Float
QUEENS CO.
SHELBURNE CO.
103
PORT HEBERT
PORT JOLI
SANDY BAY
ATLANTIC OCEAN
NB
MAP AREA
Sheet 20P/15W
0 1 2 3 4 5 6
km
Modified after Oldale, 1959
LEGEND
DEVONIAN
Biotite-muscovite granite, fine- to medium-grained
ORDOVICIAN
Goldenville Formation
Quartzite, schist, gneiss
SYMBOLS
Anticline
Syncline
Fault (horizontal)
Pegmatite, massive
Foliation (inclined, vertical, dip unknown)
Schistosity (inclined, vertical, dip unknown)
Beryl
Be
Contact (approximate, assumed)
Joints (vertical)
Pegmatite dyke

Figure 13. Geology map showing beryllium occurrences at Port Mouton Island, New Building Cove, Sandy Bay and Hunts Point, Queens County.

The Jordan River property was exposed by stripping and trenching in 1960 by Cadamet Mines Ltd. and revealed a vein averaging a 0.9 m width over a distance of 80 m (Cadamet Mines Ltd., 1960). In 1961, Talisman Mines Ltd. drilled four holes on the showing and intersected the main vein which was wider at a vertical depth of 20 m (65 ft.) than at surface and revealed two additional veins (Geisler, 1961). The average assay of 0.46% BeO was determined by Oldale (1959) using a berylometer. Whether this occurrence or others listed above are of economic significance depends on the price, minability, reserves and grade. All of these properties require additional work.

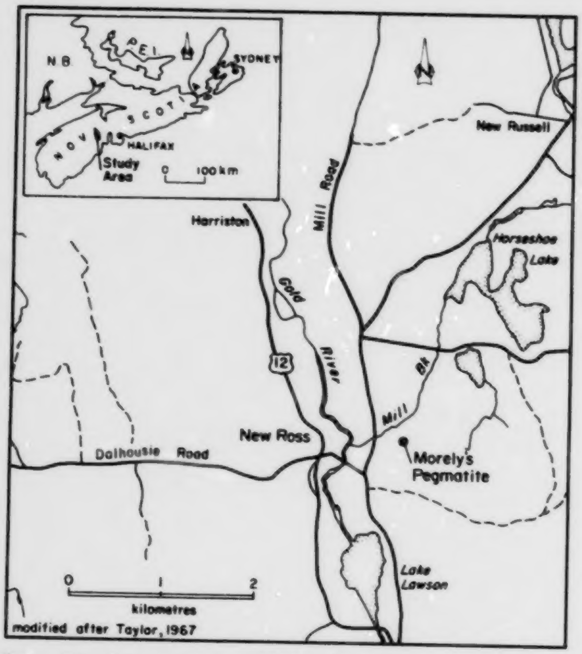

N B
P E I
N
SYDNEY
N O V A S C O T I A
HALIFAX
Study Area
0 100 km
N
New Russell
Mill Road
Harriston
Horseshoe Lake
Gold River
12
Mill Bk
New Ross
Dalhousie Road
Morely's Pegmatite
Lake Lawson
0 1 2
kilometres
modified after Taylor, 1967

Figure 14. Location map of Morely's pegmatite at New Ross, Lunenburg County.

CHAPTER 5. BRUCITE

Brucite is a magnesium hydroxide with the chemical formula $Mg(OH)_2$. It is white to pale green, grey or blue, has a pearly lustre on cleavage surfaces, elsewhere it has a waxy to vitreous lustre. Brucite has a hardness of 2.5 on Mohs scale, a specific gravity of 2.39 and belongs to the hexagonal crystal system with perfect cleavage along (001). The mineral is found in three very distinct forms: the platy or foliate type; the fibrous material usually elongated on an *a* axis; and massive material with a soapy appearance (Berry and Mason, 1959). Brucite is infusible and glows before a blow pipe. It is easily soluble in hydrochloric acid.

Brucite is usually associated with calcite, aragonite, talc, magnesite and other more rare minerals and is typically a low temperature hydrothermal vein material. It commonly occurs in metamorphosed dolomitic limestones.

USES

Brucite is one of several minerals used as a source for magnesium metal. In 1986, 49% of magnesium metal was used in the manufacture of aluminum-based alloys. Magnesium castings and wrought products accounted for 20%; reducing agent, 10%; cathodic protection, 6%; manufacture of nodular cast iron, 2%; and other uses, 13% (Kramer, 1987). Aluminum alloys containing magnesium metal are used primarily in beverage cans and the automotive industry. In the automotive industry, applications make use of its high strength and light weight.

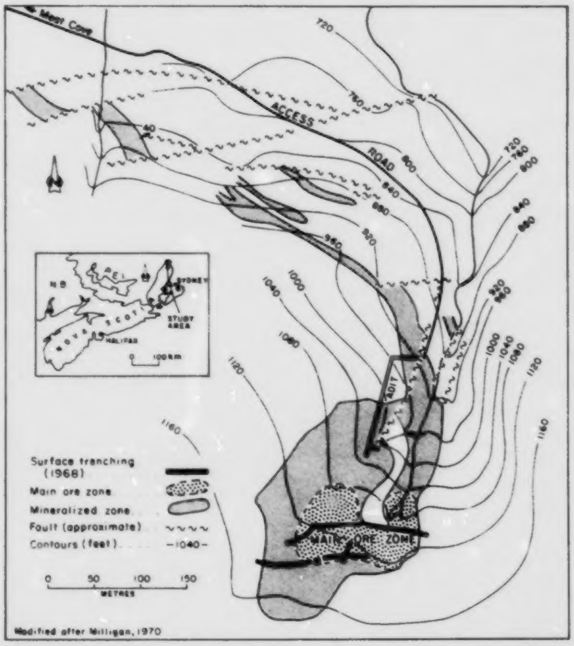
Developments in rapid solidification technology, high purity magnesium alloys with improved physical properties, and the continued penetration of magnesium into automotive applications indicated a potential to increase domestic magnesium consumption significantly. In addition, advances in aluminum can fabrication technology may result in the development of aluminum food cans which contain an average of 3.5% magnesium (Kramer, 1986b).

WORLD SUPPLY

Resources from which magnesium compounds may be recovered range from large to virtually unlimited and are globally widespread. Identified world resources of brucite are estimated to be several million tonnes (Kramer, 1987).

NOVA SCOTIA POTENTIAL

The brucite deposit with the best potential for development occurs near Meat Cove, Inverness County (Fig. 15). A brucite marble unit extends approximately 2.4 km across the property. The crystalline limestone lithologically resembles the Hadrynian George River Group carbonates found in southeastern Cape Breton Island and appears to be a remnant in the Devonian granite and syenite. This limestone remnant hosts the zinc, brucite and associated minerals.



Modified after Milligan, 1970

Figure 15. Location map showing brucitic marble deposit at Meat Cove, Inverness County.

The extension of the crystalline limestone unit has been traced (Dunbar, 1965) over a strike length of 730 m and outcrops have been found 1280 m southeast of the main section. The indicated widths range from 18 m on the northern end to approximately 120 m on the southern end. The dips range from horizontal to 45° east.

Reserves of 4.3 Mt grading 12-18% brucite and 4.0% zinc have been defined by trenching and diamond drilling (Dunbar, 1965). Economic concentrations of cadmium, germanium and silver are indicated. A grab sample collected near the adit during a 1988 visit by the author contained 20.32% brucite and assayed as shown in Table 8.

Table 8. Analysis of Meat Cove brucite ore collected by the author during 1988 visit to deposit.[*]

		%		
Ca	MgO	H_2O	LOI	Fe
35.30	17.19	6.27	37.05	1.67

	ppm		
Zn	Cd	Ag	Ge
7000	19.3	3.0	2.3

[*] Analyzed by Minerals Engineering Centre, Technical University of Nova Scotia, Halifax.

The property historically has been explored for its zinc potential, but the contained brucite, cadmium, germanium and possible silver concentrations all add to the economic viability of this property.

CHAPTER 6. CELESTITE

Celestite is part of the sulphate group of minerals with the chemical formula $SrSO_4$. It belongs to the orthorhombic system, dipyramidal class, which is expressed in a number of different habits. The most common habit is thin to thick, tabular and elongated, massive with an often fine- to coarse-grained, granular texture (Felderhof, 1978).

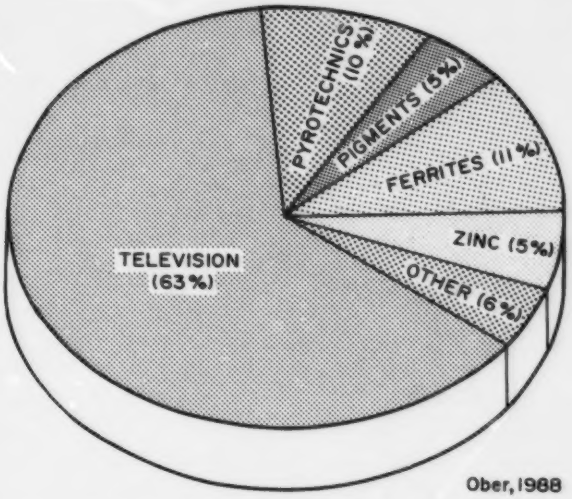
Celestite is brittle, has an uneven fracture and a hardness ranging from 3 to 3.5 on Mohs scale. It has a perfect cleavage along (001) and good cleavage along (210). The specific gravity of celestite is 3.97 and it is insoluble in acids. Celestite occurs in a variety of colours, ranging from white to blue, red, brown, green and grey. It is transparent and translucent. White, grey and blue are the most common colours with the characteristic pale, celestial blue variety giving the mineral its name (Felderhof, 1978). Impurities are thought to cause the various colours, however, the celestial blue is believed to be produced by irradiation. Celestite emits a crimson flame when flame tested.

USES

Celestite is the principal economic strontium mineral and is composed primarily of strontium sulphate. Over 95% of the world's production is consumed by the chemical industry for conversion to various strontium compounds, the most important being strontium carbonate and strontium nitrate.

Strontium carbonate's primary use today is in colour television tube glass where it filters out harmful radiation (Fig. 16). It is also used in the production of ferrites for ceramic permanent magnets. Strontium nitrate is used principally in the pyrotechnic industry because the bright crimson red flame that is emitted upon oxidation is ideally suited for the manufacture of safety flares. Strontium compounds are also utilized in greases, alloys, anticorrosive paints, ceramics and pharmaceuticals (Berry and Mason, 1959) (Tables 9 and 10).

Timminco, a Haley, Ontario, based specialty ferrous and nonferrous metals and adhesive producer is currently the largest producer of strontium metal in the world. Celestite, or strontium sulphate, is converted to strontium carbonate in the Haley processing plant. Strontium carbonate is then used to produce pure strontium metal which is used because of the strength it imparts to aluminum while adding very little additional weight. Surplus strontium carbonate is sold to other end users listed in Tables 9 and 10. Timminco currently imports its raw strontium carbonate from Europe, but would like to secure its own source of supply. The company was granted a mineral exploration licence by the Nova Scotia Department of Mines and Energy to evaluate the feasibility of reopening the former Kaiser Aluminum and Chemical Corporation's MacRae property open-pit mine at Enon in the Loch Lomond Valley, Cape Breton County, which closed in 1976 (Fig. 17).



Ober, 1988

Figure 16. Diagram showing the different applications of celestite.

NOVA SCOTIA POTENTIAL

The most promising celestite deposit in Nova Scotia is the MacRae property at Enon, Cape Breton County, which has 450 000 t of proven reserves in situ (Forgeron, 1977). The ore reserves grade about 54% celestite. A mothballed grinding and flotation mill near the deposit has the capability of recovering 80-84% of the strontium from the ore. This deposit and two others (the Amax and Enon properties) adjacent to it represent the best potential for celestite development within the Province (Fig. 17). These are well documented by Forgeron (1977).

A deposit at Beckwith, Cumberland County, contains high grade celestite ore, but a detailed exploration program followed by an additional diamond drilling program in 1986 failed to find continuity and extent of the ore zone (Felderhof, personal communication). Other occurrences of celestite within Nova Scotia are well documented by Felderhof (1978) and will not be repeated in this report.

Table 9. United States estimated distribution of primary strontium compounds, by end use, 1978-1987.[*]

End Use	1978	1979	1980	1981	1982	1983 (per cent)	1984	1985	1986	1987
Electrolytic production of zinc	3	7	5	4	3	3	6	6	6	5
Ferrite ceramic magnets	5	10	5	5	7	9	11	12	11	11
Pigments and fillers	NA	4	4	4	4	4	8	8	7	5
Pyrotechnics and signals	17	16	12	15	15	14	14	15	10	10
Television picture tubes	66	57	67	65	62	64	53	52	60	63
Other	NA	6	7	7	9	6	8	7	6	6
Total	91	100	100	100	100	100	100	100	100	100

NA Not Available.

[*] from Ober, 1988.

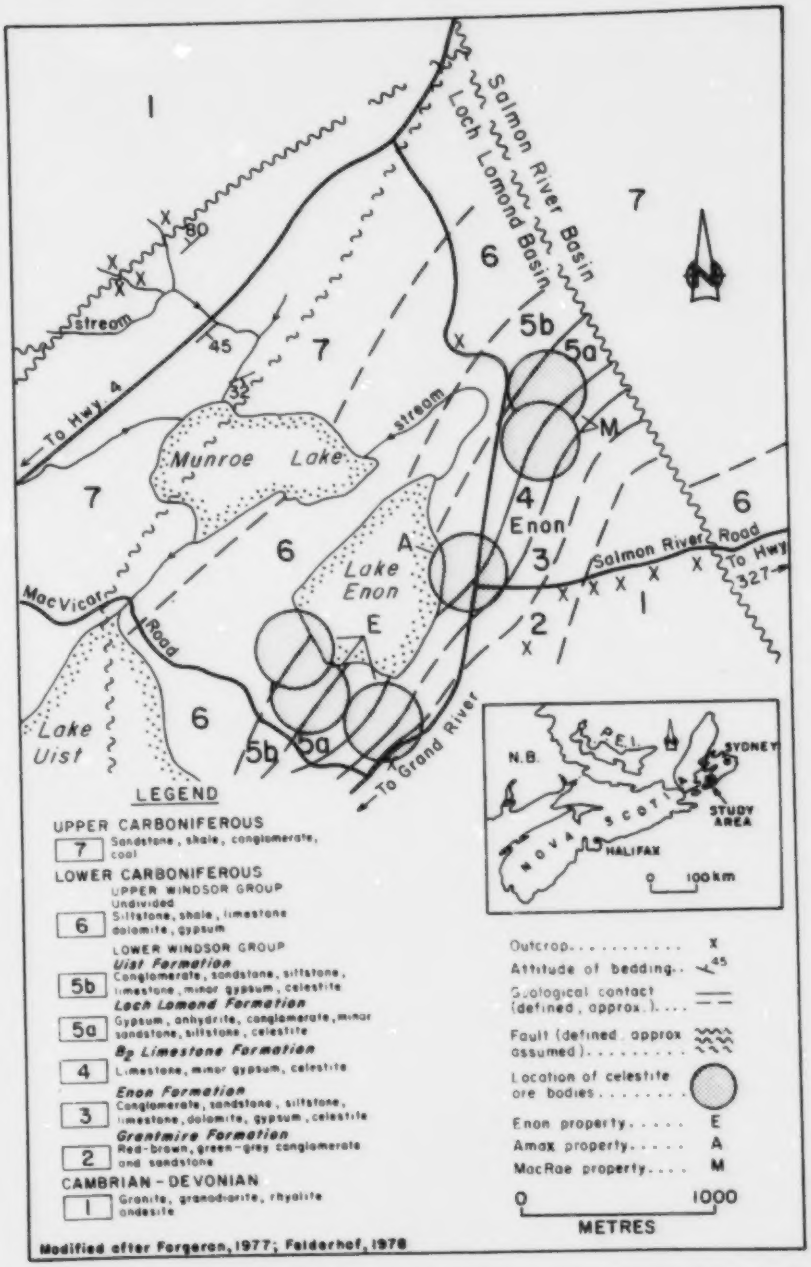
Table 10. Physical properties and uses of selected strontium compounds.[*]

Compound	Chemical Formula	Molecular Weight	Specific Gravity	Melting Point, °C	Primary Uses
Carbonate	$SrCO_3$	147.63	3.70	1497	Ceramics and glass
Chloride	$SrCl_2$	158.53	3.052	873	Desensitizing toothpaste
Chromate	$SrCrO_4$	203.61	3.895	n/a	Anticorrosive paint
Nitrate	$Sr(NO_2)_2$	211.63	2.986	570	Pyrotechnics
Oxalate	$SrC_2O_4 \cdot H_2O$	193.64	n/a	n/a	Pyrotechnics
Oxide	SrO	103.62	4.70	2430	Ceramics and glass
Peroxide	SrO_2	119.62	4.56	[#]	Pyrotechnics
Sulfate	$SrSO_4$	183.68	3.96	1605	As celestite, raw material for all other compounds
Sulfide	SrS	119.68	3.70	2000	Intermediate material in conversion of celestite to carbonate.

n/a not applicable.

[#] decomposes on heating.

[*] from Ober, 1988.


1
7
6
Salmon River Basin
Loch Lomond Basin
80
45
32
stream
To Hwy. 4
Munroe Lake
5b
5a
M
4
Enon
A
3
Salmon River Road
To Hwy 327
Lake Enon
MacVicar Road
E
2
Lake Uist
To Grand River
N.B.
P.E.I.
SYDNEY
STUDY AREA
NOVA SCOTIA
HALIFAX
0 100 km
LEGEND
UPPER CARBONIFEROUS
7 Sandstone, shale, conglomerate, coal
LOWER CARBONIFEROUS
UPPER WINDSOR GROUP
Undivided
6 Siltstone, shale, limestone dolomite, gypsum
LOWER WINDSOR GROUP
Uist Formation
5b Conglomerate, sandstone, siltstone, limestone, minor gypsum, celestite
Loch Lomond Formation
5a Gypsum, anhydrite, conglomerate, minor sandstone, siltstone, celestite
B2 Limestone Formation
4 Limestone, minor gypsum, celestite
Enon Formation
3 Conglomerate, sandstone, siltstone, limestone, dolomite, gypsum, celestite
Grantmire Formation
2 Red-brown, green-grey conglomerate and sandstone
CAMBRIAN - DEVONIAN
1 Granite, granodiorite, rhyolite andesite
Outcrop........... X
Attitude of bedding.. 45
Geological contact (defined, approx.)....
Fault (defined, approx assumed)........
Location of celestite ore bodies........
Enon property..... E
Amax property..... A
MacRae property.... M
0 1000
METRES

Modified after Forgeron, 1977; Felderhof, 1978

Figure 17. Location map showing Loch Lomond celestite deposits, Enon, Cape Breton County.

CHAPTER 7. GARNET

Garnet is truly a unique mineral. Characteristics such as high hardness, sharp, consistent fracture, acid resistance, high specific gravity, nontoxicity and attractive colour are some of the factors which have resulted in the increasingly diverse use of garnet in industrial applications.

The garnets comprise a group of isomorphous minerals with the general formula $X_3Y_2(SiO_4)_3$ in which X may be Ca, Mg, Fe^2 or Mn^2, and Y may be Al, Fe^3 or Cr^3, sometimes in part Ti or Mn^3. Table 11 follows giving names used for the minerals with their components (Berry and Mason, 1959).

Table 11. Garnet minerals and their components.*

Species	Formula	Density
Almandite	$Fe_3Al_2\ (SiO_4)_3$	4.32
Pyrope	$Mg_3Al_2\ (SiO_4)_3$	3.58
Spessartite	$Mn_3Al_2\ (SiO_4)_3$	4.19
Grossularite	$Ca_3Al_2\ (SiO_4)_3$	3.59
Andradite	$Ca_3Fe_2\ (SiO_4)_3$	3.86
Uvarovite	$Ca_3Cr_2\ (SiO_4)_3$	3.78

*from Berry and Mason, 1959.

The composition of naturally occurring garnets seldom approaches the formulas given above, as a result of extensive atomic substitution. The specific name applied is that of the component present in the largest amount.

Garnets are typically minerals of metamorphic rocks, although they have been found in some igneous rocks. They are resistant to both mechanical and chemical breakdown and occur as detrital minerals in sands and sandstones. Specifically they differ somewhat in their mode of occurrence as summarized below:

Almandite:	The common garnet of schists and gneisses is usually almandite. It may also be found in granites, rhyolites and pegmatites.
Pyrope:	Less common than most other garnets, pyrope occurs in ultrabasic igneous rocks and serpentines derived from them, and in high grade magnesium-rich metamorphic rocks.
Spessartite:	Garnets from granite pegmatites are often spessartite or intermediate between spessartite and almandite; spessartite also occurs in metamorphosed manganese bearing rocks.
Grossularite:	Grossularite is typically formed by the contact or regional metamorphism of impure limestones and is thus often associated with calcite, wollastonite and idocrase. Grossularite commonly contains combined water, as a result of the partial substitution of $(OH)_4^{-4}$ for $(SiO_4)^{-4}$ in the structure.
Andradite:	Andradite is formed by the metasomatic alteration of limestones by iron bearing solutions, and commonly occurs associated with ore deposits in calcareous rocks.
Uvarovite:	Uvarovite is rare and occurs in association with chromite in serpentine.

USES

Traditionally, garnet has been an important medium to the abrasives industry. Garnet is one of the oldest natural abrasives known to man and has exceptional abrasive qualities which, despite advances in artificial abrasive technology, remain unequalled in many metal, glass and wood finishing applications. With energy costs for the production of artificial abrasives increasing, the demand for high quality, readily available natural garnet has risen sharply (Industrial Garnet Extractors, 1983).

Garnet has become the preferred media in many fluid filtration applications because of its resistance to acidic and chemical solutions, high specific gravity, efficient particle-trapping granular shape and low cost. Applications range from small, single-medium filters, such as swimming pools, to dual-media municipal and industrial systems, to technically advanced multi-media (garnet, quartz and anthracite) commercial systems.

The physical and chemical properties of garnet make it ideal for a wide variety of applications where skidding, slipping, high wear and acid exposure are problems. Garnet can be mixed with all types of resins, epoxies, paints, cements and other bonding agents to provide many desirable flooring, surfacing and coating characteristics.

Garnet is one of a very few minerals which has a high specific gravity, a high hardness, acid resistance and at the same time is abundant enough in nature to be used in the various types of heavy media applications. Typical uses include special grouting cements for water wells; engineering and petroleum applications; low to medium level radiation shielding; and other situations where a high density-to-volume ratio is required (Toon, 1986).

WORLD SUPPLY

The United States is the largest garnet producer accounting for over 60% of the world's production; the remainder is produced primarily, in order of production by India, Australia, China and the U.S.S.R. (Austin, 1987). Within the United States there are three main producers, two in New York State and one in Idaho. The two New York operations are small with questionable reserves; the Idaho deposit hosts two mines and a single mill; a deposit in Maine is considered one of the largest in the world with an unusually high garnet concentration of 50-60% (Austin, 1987). This deposit produced briefly in 1989, but financial problems placed this operation in bankruptcy in 1990.

Annual world production is approximately 50 000-60 000 t with the United States accounting for approximately 35 000 t per year (Austin, 1987). World reserves of garnet are considered large.

NOVA SCOTIA POTENTIAL

There are many known occurrences of garnet within Nova Scotia. They are contained mainly in schists near intrusions of granite and in pegmatites cutting through the granite. These occurrences are documented in the Nova Scotia Department of Natural Resources mineral occurrence files and selected assessment reports.

The deposit, with perhaps the most potential, occurs as a garnetiferous graphitic micaceous schist found outcropping along the shoreline at Chegoggin Point, Yarmouth County (Fig. 18). Belonging to the White Rock Formation of Siluro-Devonian age, the strata cuts the coastline obliquely with a regional strike of N35°E and dipping 80°E to vertical. Numerous mica schist beds have been identified, some containing a few small garnets. One bed, averaging 3 m in thickness, is rich in almandite garnets.

During October 1987, a 2 t bulk sample was collected from the garnet-rich schist bed exposed along the coast. A 20 kg portion of this sample, containing 50-60% garnets, was forwarded to the Canadian Centre for Mineral and Energy Technology (CANMET), Industrial Minerals Laboratory in Ottawa for testing the possibility of concentrating the garnet. The testing was successful. Gravity concentration, employing laboratory shaking tables, concentrated the garnet in the -840 +420 μm fraction to 70-75% garnet; in the -420 +150 μm fraction to 80-85% garnet; and in the -150 μm fraction to 95% garnet. Although garnet was effectively liberated in the -2.4 mm +840 μm fraction, concentration by tabling was not possible due to a combined effect of similarity in shape and specific gravity between garnet and chlorite, which was more critical at coarser sizes than finer sizes. Garnet in the -840 +420 μm fraction was further concentrated by reverse flotation of chlorite to 85% garnet. A complete report by Andrews (1988) is contained in Appendix 1.

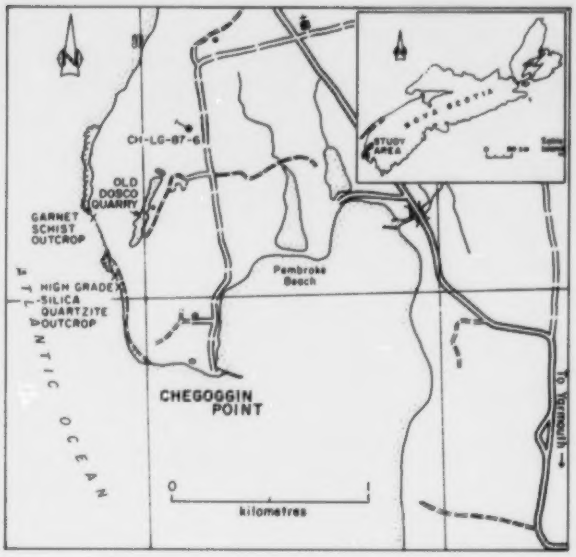


Figure 18. Location map showing high grade quartzite and garnet schist outcrops at Chegoggin Point, Yarmouth County. Drillhole CH-LG-87-6 completed during this program is shown northeastward along strike from the abandoned DOSCO silica brick Quarry.

This particular garnet-rich bed is exposed along the coast line and appears to be continuous inland to the shore of Island Pond, (Utley Lake, historical name) a distance of approximately 3 km (Fig. 19). The potential for similar garnet-rich beds is good in the adjacent rocks and in fact thinner beds have been intersected in diamond-drill holes targeted to test the high grade silica deposit to the south. DDH CH-LG-87-6 completed during this project intersected such garnet-rich beds (Fig. 18).

Very fine grained garnet occurs in the andalusite-rich mica schist at Doughboy Point, Guysborough County (Fig. 4). The garnets occur as clusters of small

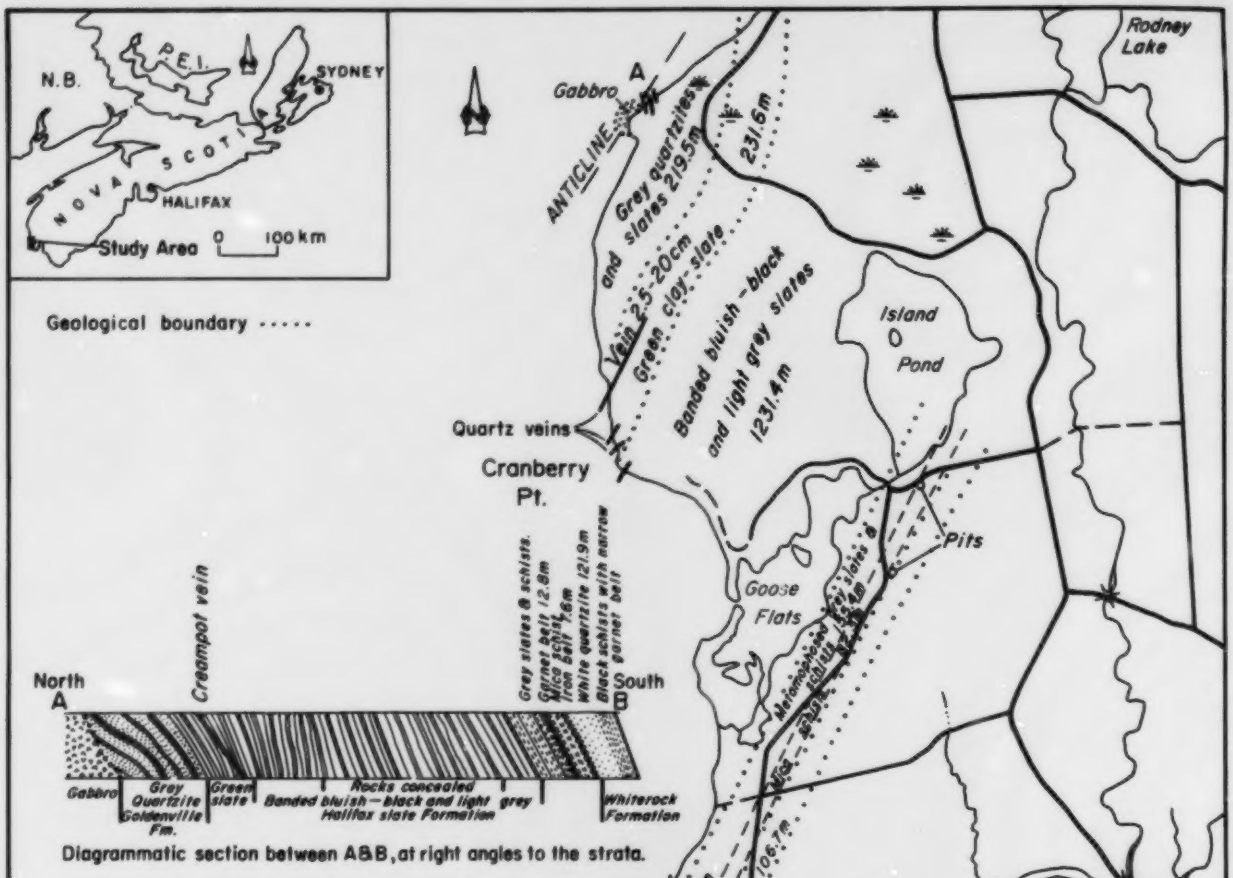

N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
Study Area
0 100 km
Geological boundary .....
Gabbro
A
ANTICLINE
Grey quartzites and slates 219.5m
Vein 2.5-20cm
Green clay-slate
Banded bluish-black and light grey slates 1231.4m
231.6m
Rodney Lake
Island Pond
Quartz veins
Cranberry Pt.
Pits
Goose Flats
Metamorphosed grey slates &
schists
Mica schist
106.7m
Garnet schist belt 11m
Iron pyrite belt
White quartzite belt
Black 74.7m
Narrow garnet belt black schists
Pembroke
Bell Ponds
Pits 4.6m
Open Cut
B
Chegoggin Pt.
Atlantic Ocean
0 1 2
kilometres
modified after Faribault, 1920
North
A
Creampot vein
Grey slates & schists.
Garnet belt 12.8m
Mica schist
Iron belt 7.6m
White quartzite 121.9m
Black schists with narrow garnet belt
South
B
Gabbro
Grey Quartzite Goldenville Fm.
Green slate
Rocks concealed
Banded bluish-black and light grey
Halifax slate Formation
Whiterock Formation
Diagrammatic section between A&B, at right angles to the strata.

Figure 19. Geological plan and section showing the garnet zone at Chegoggin Point, Yarmouth County.

subhedral crystals about 0.02-0.05 mm in diameter. The clusters are about 0.2 mm across. The garnets are concentrated in thin bands cutting through the rock and are also distributed fairly uniformly throughout and appear to make up approximately 30% of the entire rock. The economic feasibility of mining this deposit for the garnet is dependent on what other commodities may be extracted as byproducts and the ease of separating the different minerals.

Other garnet occurrences with little apparent potential for economic development are located in Shelburne County at Negro Harbour, Round Bay, Port La Tour and in road cuts from Shelburne to Jordan Falls (Fig. 20). Large crystals of almandine garnets up to 30 mm in diameter have been found in rounded granodiorite boulders near Ten Mile Lake in the Liscomb Game Sanctuary, Halifax County, but to date no bedrock source has been located.

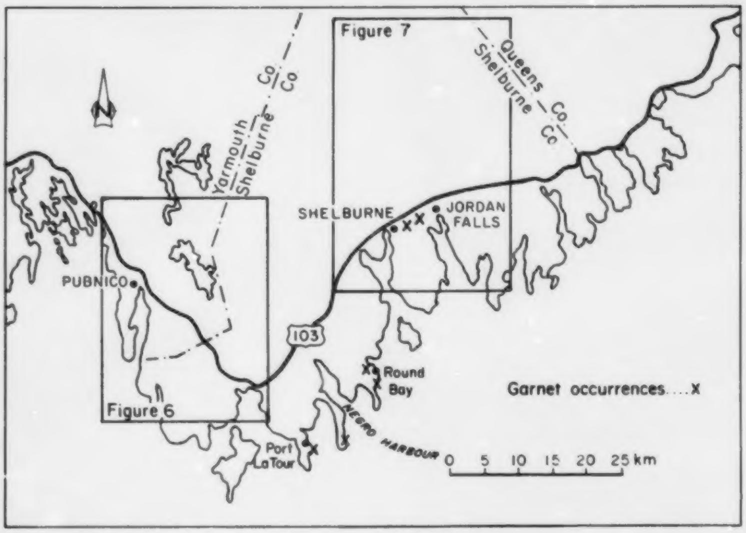

N
Figure 7
Queens Co.
Shelburne Co.
Yarmouth Co.
Shelburne Co.
SHELBURNE
JORDAN FALLS
PUBNICO
103
Round Bay
Garnet occurrences....X
Figure 6
Port La Tour
NEGRO HARBOUR
0 5 10 15 20 25 km

Figure 20. Location map showing garnet occurrences at Negro Harbour, Round Bay, Port La Tour and Highway 103 between Shelburne and Jordan Falls, Shelburne County.

CHAPTER 8. GRAPHITE

Graphite is a natural form of carbon. Natural graphite is a lustrous, black carbon mineral, crystallized in the hexagonal system with rhombohedral symmetry. Flake graphite is opaque, flexible and sectile, and exhibits perfect basal cleavage. Natural graphite is unctuous and soft with a hardness of 1-2 on Mohs scale. It is black in colour and produces a black streak on glazed porcelain. The specific gravity of graphite is 2.23. Graphite is an excellent conductor of heat and electricity, and it melts at 3000°C. It is extremely resistant to acid, chemically inert and highly refractory (Prud'Homme, 1985).

Natural graphite occurs in metamorphic rocks produced by regional or contact metamorphism. **Amorphous graphite** is a microcrystalline graphite formed by crystallization of the carbon from organic sediments such as coal. The graphite occurs as distorted seams of minute microcrystalline particles intermixed with ungraphitized material. The graphite content may vary from 15-98% depending on the degree of metamorphism and the original carbon content in the sediments. **Crystalline lump**, or **vein graphite**, occurs in the form of massive vein or circular accumulation probably formed from hydrothermal origin. The graphite occurs along the contacts of intrusive rocks with limestone. Such occurrences appear in foliated or columnar forms. **Crystalline flake graphite** is found disseminated in metamorphosed siliceous or calcareous sedimentary rocks such as marble, gneiss and schist (Prud'Homme, 1985).

Commercially, natural graphite is classified as crystalline flake or amorphous graphite depending on particle size. **Crystalline flake** is defined as thin flakes which could be classified from coarse to fine and which are graded according to their graphitic carbon content. **Amorphous grade** is applied to microcrystalline graphite sold for low value uses such as foundry facings. It is graded on graphitic carbon content which may vary from 50-90%.

USES AND SPECIFICATIONS

The many varied uses of natural graphite depend on its physical and chemical properties. The strength of graphite increases as you heat it. It has a high thermal conductivity and a low absorption coefficient for X-rays and electrons. Flake graphite enhances anisotropy in bodies where forming processes, such as extrusion and pressing, align the flakes. It resists oxidation better than granular graphite.

Flake graphite is used in the manufacture of crucibles for the steel, nonferrous and precious metals industries. It is preferred over microcrystalline graphite because it burns more slowly, has a high attrition resistance and imparts structural strength through the orientation of the flakes. For this use, graphite must be of large flake size, >150 μm, with a carbon content of at least 90%, although finer flake size with a carbon content in the 80% range is used if modern silicon carbide-graphite crucibles are used instead of the clay-graphite variety.

In ramming mixes, graphite imparts high refractoriness, low thermal expansion and high resistance to extreme temperature, therefore microcrystalline graphite, containing between 80-90% carbon, is required.

The emergence of magnesia-carbon brick in steel furnace linings, of alumina-carbon refractories in ladles and nozzles, and of silicon carbide-carbon refractories in blast furnaces has increased the demand for graphite because it improves resistance to thermal shocks and erosion. Large flake graphite, >425 μm, is required with a carbon content >85% and an ash content <10%. Impurities such as silica, alumina and iron are detrimental and must be avoided.

Graphite is used in brake linings because it reduces the rate of wear. Fine crystalline graphite <75 μm and a high carbon content of at least 98% are required although graphite down to 90% carbon content can be used if abrasive impurities such as silica are at a very low level.

For many years, graphite has been used in dry cell zinc-carbon batteries because of its electrical conductivity. Fine grained carbon, <75 μm, or microcrystalline graphite with a minimum carbon content of 85-90% is required. Alkaline batteries require a purer natural graphite with a carbon content of at least 98%. The graphite must be free of metallic impurities such as copper, cobalt and antimony.

Electric motor components use a wide variety of graphite, natural or synthetic. Powdered graphite, 150 μm, with a minimum carbon content of 95-99% is used. Lump graphite, low silica microcrystalline graphite and synthetic graphite are usually used.

In powder metallurgy where steel is reinforced by the absorption of carbon, high purity graphite is required for the sintering. It also acts as a lubricant and as a source of carbon. Dry powder graphite should have an average particle size of 5 μm and must have a carbon content in the 96-99% range.

Graphite's properties of softness, low friction, inertness and heat resistance make it sought after as an industrial lubricant. Fine crystalline graphite, <1 μm, with a carbon content between 96 and 99% is specified. In paint manufacture, graphite is used to protect metal surfaces exposed to corrosive environments and to eliminate the accumulation of static electricity in floor coatings. Microcrystalline graphite of carbon content in the 50-55% range is required (Prud'Homme, 1985).

Natural graphite has been used for many years in the manufacture of pencils. The degree of hardness of a pencil is determined by its clay to graphite ratio. A finely ground graphite with a high carbon content of >90% is usually required although a microcrystalline graphite with a carbon content of 80-82% is often used in the cheaper grade of pencils.

For foundry applications such as mould coating, graphite prevents the adhesion of metals. Foundry facings are usually made of lump graphite or microcrystalline graphite, between 53 and 75 μm, with a low carbon content in the range of 40-70%. Iron foundries use microcrystalline graphite as a recarburizer for raising the carbon content of iron melted in electrical furnaces from charges containing large proportions of scrap.

Other uses for natural graphite include engineering components, mechanical seals, polishes, rubber products and explosives.

PRODUCTION AND OUTLOOK

Graphite is not a new industrial mineral by any means, and the marketplace has been small with annual world production of natural graphite ranging from 600 000-700 000 t for the last four years (Taylor, 1986). The future demand for natural graphite is expected to increase at an average annual rate of about 1.5% through to the year 2000 (Prud'Homme, 1985). Growth will be both enhanced and limited by technological shifts and availability of alternative materials.

North America will remain largely dependent on foreign sources for graphite. No shortage of graphite is foreseen as world resources of natural graphite appear more than abundant. However, the availability of the low cost, high grade graphite could be affected by the policies of foreign governments in supplying countries. Therefore a market exists for a secure source of coarse, crystalline, flake graphite, especially in the United States and Japan where graphite is considered a strategic mineral.

The United States Bureau of Mines (Taylor, 1986) listed 21 producer nations of graphite with 12 nations supplying >96% of the market. The main producers are China, U.S.S.R., South Korea, West Germany, Brazil, Austria and Mexico.

Pricing graphite is not an easy task due to the many different varieties and specifications and also producer secrecy. Prices have risen in recent years with crystalline flake at $US 648 per ton, Mexican amorphous graphite at $US 49 per ton, all types of Sri Lankan lump graphite selling at $US 932 per ton, and other natural graphite (mainly fine crystalline flake and dust) at $US 541 per ton. Average price for natural graphite at the point of consumption was $US 94 per ton for crystalline graphite (mostly crystalline flake, some crystalline dust and a little lump graphite). Amorphous graphite containing small amounts of amorphous-synthetic graphite mixtures, was selling at $US 618 per ton (Taylor, 1986).

NOVA SCOTIA POTENTIAL

There are many recorded graphite occurrences within Nova Scotia and a list of those on file with the Nova Scotia Department of Natural Resources is given in Table 12. Glendale, Inverness County, is the deposit with the most development potential (Fig. 21).

Table 12. Recorded graphite occurrences in Nova Scotia, 1989.

Occurrences with Development Potential

1. **Glendale, Inverness County:** 2.4 km up River Denys Mountain Road, 2000 m west to several old shafts and recent trenching (Fig. 21).

2. **Lime Hill, Inverness County:** geophysical work has outlined a large conductive zone measuring 30 x 150 m which appears to be graphite.

3. **Christmas Island, Cape Breton County:** 5.6 km from Christmas Island along the road leading to Eskasoni, Cape Breton County, old shaft, dumps containing very weathered graphite shale are located 183 m east of road.

Minor Occurrences

4. **River Denys Road, Inverness County:** approximately 2.0 km southwest of River Denys Road school in the bed of a small creek an exposure of amorphous graphite over 1.5 m wide.

5. **Halfway River, Gaspereau River and Black River, Kings County:** graphite shale/slate occurrences along the Rivers.

6. **Partridge Island, Cumberland County:** graphite mineralization along shear zones.

Amorphous graphite occurs at Glendale in a zone striking north-south within Precambrian George River

Group metalimestone close to a sandstone contact (Messervey, 1933). The zone or bed is 15-30 m wide and can be traced for over 1000 m. It is composed of crushed graphitic schists and altered coal seams. The zone appears to be fairly uniform across its width, but contains large inclusions of altered limestone and nodules of pyrite. The graphite occurs mainly in the form of contorted plates, with lesser amounts as fine, black powder. There appears to be two more parallel beds to the west at distances of 92 and 184 m having widths of 15 and 30 m respectively. These beds are thought to be isoclinal repetitions of the main bed.

Previous reports of assay values had graphite carbon values of 41.9% and 47% in the southern zones and 60% graphitic carbon in the northern zone (Carbontec Industries Limited, 1986). Samples collected by the author during 1986 and 1987 had total carbon values of 41.8% for the southern zone and 31.7% for the northern zone (Fig. 21).

Hand samples were collected by Messervey (1931) who noted that the ore consisted of contorted plates of graphitic material among layers of siliceous and carbonaceous rock.

Assay results for carbon content of Messervey's (1931) samples and others are included in Table 13. Messervey (1931) noted that carbon content increased at depth due to the high reading for a sample taken from one of the old tunnels.

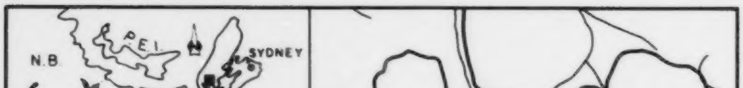

N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
Study Area
HALIFAX
0 100 km
RIVER DENYS MOUNTAIN
MacColls
Brook
River Denys Road
0 1 2
kilometres
Northern Zone
Graphite stockpile
Southern Zone
105
Glendale
Glendale Bk
Graphite stockpile
Exploration trench
Old adit
Modified after Hill, 1989

Figure 21. Location map showing graphite deposit at Glendale, Inverness County. See Table 13 for analyses.

Additional work in the form of diamond drilling and trenching is required on this deposit to determine the extent and quality of the main bed and also to delineate and obtain samples for assay of the other previously unexplored beds.

Table 13. Carbon content analyses of samples collected from the graphite occurrence at Glendale, Inverness County. See Figure 21 for approximate locations.

Sample Number	Carbon Content %
(Messervey, 1931)	
M-1 Southern Zone	47.5
M-2 old adit	41.2
M-3 Northern Zone	60.0
A-1 Northern Zone	39.0
A-2 Southern Zone	27.1
(Carbontec Industries Limited, 1986)	
1 Southern Zone	41.9
2 Southern Zone	47.0
1 Northern Zone	60.0
Sampled by author	
1 Southern Zone	41.8
1 Northern Zone	31.7

CHAPTER 9. LIMESTONE AND DOLOMITE

Limestones can be classified either as chemical precipitate or as organic sedimentary rock. Since sea water is nearly saturated with calcium carbonate, slight changes in water temperature or chemical composition can bring about the precipitation of calcite out of solution. The most prevalent form of limestone is as organic sedimentary rock. These are comprised of the fossil remains of sea organisms or of calcareous shell material that has been reworked and consolidated (Luke and MacDonald, 1988).

Limestone, in its purest form, is known as calcite with a chemical composition of $CaCO_3$ (calcium carbonate) made up of 56% CaO (lime) and 44% CO_2 (carbon dioxide). Limestone often contains small quantities of impurities such as magnesium, iron, manganese and lead. Dolomite is a magnesium limestone or a carbonate of calcium and magnesium $CaMg(CO_3)_2$. Pure dolomite contains 47.8% CO_2 (carbon dioxide), 30.4% CaO (lime) and 21.8% MgO (magnesium). Iron and manganese carbonates are also sometimes present (Luke and MacDonald, 1988).

There are many varieties of limestone. It can be coarse- to very fine-grained in texture and hard to soft in composition. The colour can vary from pure white to grey, buff, yellow, red, green, brown, blue to black and may be laminated. Limestone may be metamorphosed to a grade where it readily accepts a good polish suitable for dimension stone and is referred to as marble.

USES

The traditional uses of limestone and dolomite include processed limestone in the paper industry where the lime is used as a causticizing agent and for bleaching paper pulp to the desired degree of whiteness. Lime is also used in the clarification and colour removal of paper mill wastes and to make precipitated calcium carbonate, a specialty pigment used in premium-quality coated and uncoated papers. Dolomitic quicklime is used as a flux in the manufacture of glass. In steel refining, quicklime is used as a flux to remove impurities such as phosphorus, silica and sulphur. Dolomitic lime is often substituted for a fraction of the high calcium lime to extend refractory life. Dead-burned lime, also called refractory lime, is used to line the bottom of open hearth steel furnaces to extend the life of the brick lining. Dead-burned dolomite is used to make tar-bonded refractory bricks used in basic oxygen furnaces.

Limestone and dolomite, in pulverized form, are used in the agricultural industry as a soil conditioner and in the mining industry for the dusting of coal mines and also to neutralize acid mine waste discharges.

The chemical industry uses lime in the manufacture of soda ash and bicarbonate of soda to recover and recycle ammonia. Quicklime is combined with coke to produce calcium carbide, which is used to make acetylene and calcium cyanamide. Lime is also used to make calcium hypochlorite, citric acid, petrochemicals and other chemicals. Other traditional uses include applications in cement manufacture, leather tanning and as an antistripping agent in hot-mix asphalt for highway surfacing.

New technology has decreased demand in some traditional markets, but it has also opened doors for limestone and dolomite consumption in new markets. Potential areas of growth are in environmental cleanup programs. The foremost of these within Nova Scotia is flue gas desulphurization in coal fired power generating plants. Since the Nova Scotia Power Corporation is committed to using Provincial resources of coal for power generation, then Provincial limestone resources have a very large and attractive market due to the high sulphur content of most Nova Scotia coal deposits. Many different processes to control sulphur emissions are presently being investigated but, regardless of the technology chosen, they all require large amounts of limestone (Webb, 1986).

The reclamation of fresh water resources damaged by acid rain represents another potential market for limestone. This is especially true in areas such as southwestern Nova Scotia where there is virtually no natural buffering from the shallow granitic soil.

Waste management has used lime for years as a disinfectant, deodorizer and fungicide and more recently as a flatulent to increase dewatering efficiency in sewage treatment plants. Such lime treated sludges are sometimes used as soil conditioners. Lime has always and still does command a share of the water treatment market due to its low cost and being environmentally preferred to alternate systems.

The filler and extender industry has a high demand for high grade limestone. In the paint, plastic and paper processing industries, limestone reduces the consumption of more expensive raw materials and in some cases adds more desirable characteristics to the finished product. Some quality restrictions for limestone entering these markets include a high brightness reading, high calcium values, and low magnesium and silica contents. Zones in some of the George River Group deposits on Cape Breton Island appear to meet the requirements of the filler industry. Samples collected from the Glencoe limestone deposit, Inverness County, during this project replaced the imported limestone presently being used in the manufacture of paint by a Nova Scotia paint manufacturer and produced a product of equal quality (Luke, 1990). This particular sample gave brightness readings of 94%, CaO_3 values of >96%, and combined SiO_2 and MgO content of <2%. Limestone of this quality has a potential market in the paint and carpet backing industries in the Atlantic region as well as the paper industry of the northeastern United States.

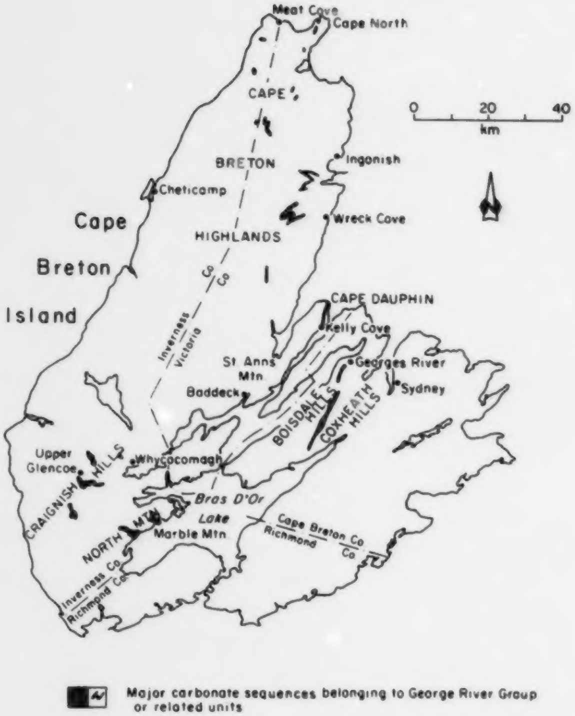
NOVA SCOTIA POTENTIAL

Limestone may be present to some extent in many geological systems within Nova Scotia, but it is only in the Precambrian George River Group and the Carboniferous Windsor Group that it attains sufficient extent, thickness and grade to be considered as having economic potential.

The older **Precambrian George River Group** limestone and dolomite deposits tend to be more crystalline, altered and much larger than the Carboniferous Windsor Group deposits. They occur only on Cape Breton Island with some deposits containing reserves in excess of 300 Mt (MacNeil, 1977). These metasedimentary rocks are enfolded with granitic rocks of different ages and make up much of the Highlands of Cape Breton Island. Bands of quartzites, slates and schists are associated with these carbonates and a variety of dykes and sills are known to be injected throughout them. These rocks form part of what is known as the Coxheath Hills, Boisdale Hills, Craignish Hills and North Mountain of Cape Breton Island. Minor occurrences are found on St. Anns Mountain and at a few isolated locations in Inverness and Victoria Counties. A few have been exploited in the past, mainly for use in steel making at Sydney, Cape Breton County (Fig. 22).

The George River Group limestones and dolomites and associated sedimentary sequences, occur in long, usually steeply dipping bands along the flanks of the granitic hills. Some of these bands are in excess of 150 m thick as indicated by diamond-drill holes at Glencoe, Inverness County, completed during this project (MacDonald, 1990a) and also previous work by MacNeil (1977).

The composition of these carbonates ranges from high calcium content to low calcium/high magnesium content and commonly varies within one deposit unlike the younger Windsor Group carbonate deposits which usually have a consistent composition throughout. Associated with the George River carbonates are impurities of silica, alumina, iron and serpentine. In areas of high temperature alteration, brucite, wollastonite, and minor magnetite, chalcopyrite, pyrite, graphite and sphalerite may occur.



Major carbonate sequences belonging to George River Group or related units

Modfied after Hill, 1989

Figure 22. Major carbonate sequences belonging to George River Group or related units of Cape Breton Island.

The Early Visean strata of the **Windsor Group** contain every variety from high calcium limestone to dolomite. These marine deposited sedimentary rocks make up over 5000 km^2 of the surface of Nova Scotia and lie unconformably, in most areas, over sedimentary rocks of continental origin of the Early Carboniferous Horton Group. In other areas, the Windsor Group directly overlies Precambrian or Early Paleozoic basement rocks. Dolomite deposits are common throughout the Windsor Group though dolomitic limestone may be a more accurate term.

Windsor Group carbonate deposits are generally much smaller than the George River Group deposits. They are usually bedded, containing varying amounts of impurities throughout, or fossiliferous in the form of shell mounds which are extremely pure but not extensive. Numerous geological disturbances since deposition of the limestone and dolomite beds have resulted in considerable faulting and folding causing the majority of the beds to be steeply dipping. For the most part, Windsor Group limestones are less crystalline and more porous than the older, more altered George River Group limestones.

The limestone and dolomite occurrences of Nova Scotia have been previously investigated in detail by the Nova Scotia Department of Mines. This work is presented in publications by Shea and Murray (1967), Murray (1975), and MacNeil (1974; 1977). Important data covering location, extent, structure and unique characteristics of the occurrences as well as detailed analyses were recorded in these reports. In order to avoid duplication of this work during this project, only deposits with excellent development potential for both traditional and newer applications were investigated. Also, any new and additional data collected on occurrences covered in these previous reports were added to the data base. The large tonnage limestone, dolomite and marble deposits of Cape Breton Island and the high calcium deposits near existing markets have been the focus of the majority of work during this project.

In an effort to better present the potential for development of the major deposits of both groups, an open file report (MacDonald, 1990b) was released in which 14 of the deposits are outlined (Fig. 23). The format is a simplified one page data sheet on each deposit outlining such pertinent data as ore reserves, grade, location, access, status (mineral rights, surface land ownership at time of release) and land use limitations which could affect development. A bibliography of the previous work on file at the Nova Scotia Department of Natural Resources Library is also included for each deposit.

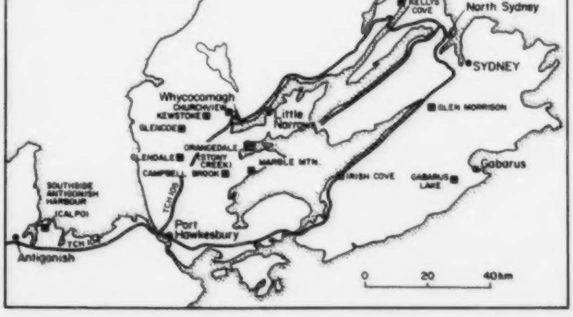


Figure 23. Location map showing major limestone/dolomite deposits in eastern Nova Scotia.

High quality, carbonate deposits containing large reserves with excellent development potential occur at Glencoe, Glendale, Kewstoke, Campbell Brook near River Denys, and Churchview all in Inverness County; Kellys Cove, Victoria County; Glen Morrison, Cape Breton County; and Southside Antigonish Harbour, Antigonish County (Fig. 23).

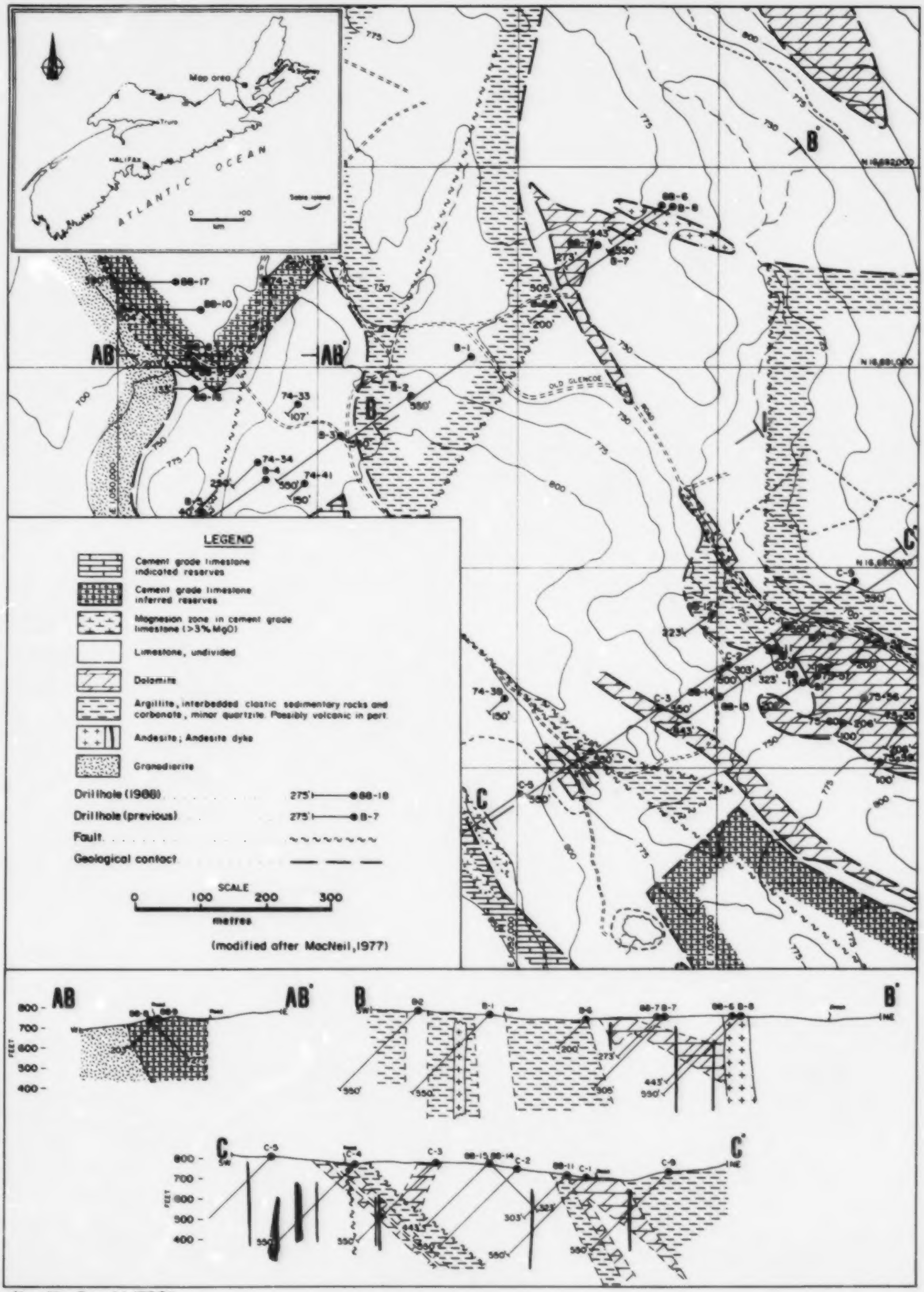
Glencoe, Inverness County

The largest known of these major Nova Scotia deposits is located at Glencoe, Inverness County, (Figs. 24 and 25) where previous work has proven in excess of 315 Mt of cement grade limestone, of which 230 Mt is metallurgical grade limestone, and over 5 Mt of dolomite (MacNeil, 1977) all belonging to the Hadrynian George River Group.

During the Various Commodities Project a 40 t bulk sample of white limestone was taken from this deposit. The majority of this sample is being held in storage for distribution to interested parties desiring a sample for testing for their particular needs. Portions have already been distributed to a Provincial paint manufacturer who successfully produced a satisfactory product from it (Luke, 1990). Testing has also been completed by the Nova Scotia Power Corporation for use in fluidized bed combustion and proven to be a satisfactory limestone for this purpose (Nova Scotia Power Corporation, personal communication).

A five hole diamond drilling program was completed around the area of the bulk sample site at Glencoe during 1988 in order to prove up reserves of white limestone along strike and at depth (DDHs 88-11, 88-12, 88-13, 88-14 and 88-15). The results of this program are contained in a separate release (MacDonald, 1990a). Unfortunately the area investigated has been subjected to extensive structural deformation due to faulting and although some white limestone was encountered, continuity of the beds cannot be traced to any extent (Fig. 24). This initial site was abandoned due to the complexity of the structure.

A second area was chosen after reviewing the results of the 1976 drilling program (MacNeil, 1977). Two holes were drilled to infill along the 1976 B line of drillholes (Fig. 24). These drillholes, 88-6 and 88-7,


Map area
Truro
HALIFAX
ATLANTIC OCEAN
Sable Island
0 100
km
LEGEND
Cement grade limestone indicated reserves
Cement grade limestone inferred reserves
Magnesian zone in cement grade limestone (>3% MgO)
Limestone, undivided
Dolomite
Argillite, interbedded clastic sedimentary rocks and carbonate, minor quartzite. Possibly volcanic in part.
Andesite; Andesite dyke
Granodiorite
Drillhole (1988) 275' 88-18
Drillhole (previous) 275' B-7
Fault
Geological contact
SCALE
0 100 200 300
metres
(modified after MacNeil, 1977)
AB
AB'
B
B'
C
C'
OLD GLENCOE
N 16,682,000
N 16,681,000
N 16,680,000
E 1,050,000
E 1,052,000
E 1,053,000
800
700
600
500
400
FEET
SW
NE
W
E

after MacDonald, 1990b

Figure 24. Geology map showing 1988 and previous diamond-drill hole locations and cross-sections at Glencoe, Inverness County. (This map is also available at a scale of 1:6000 (MacDonald, 1990c) to overlay MacNeil, 1977.)

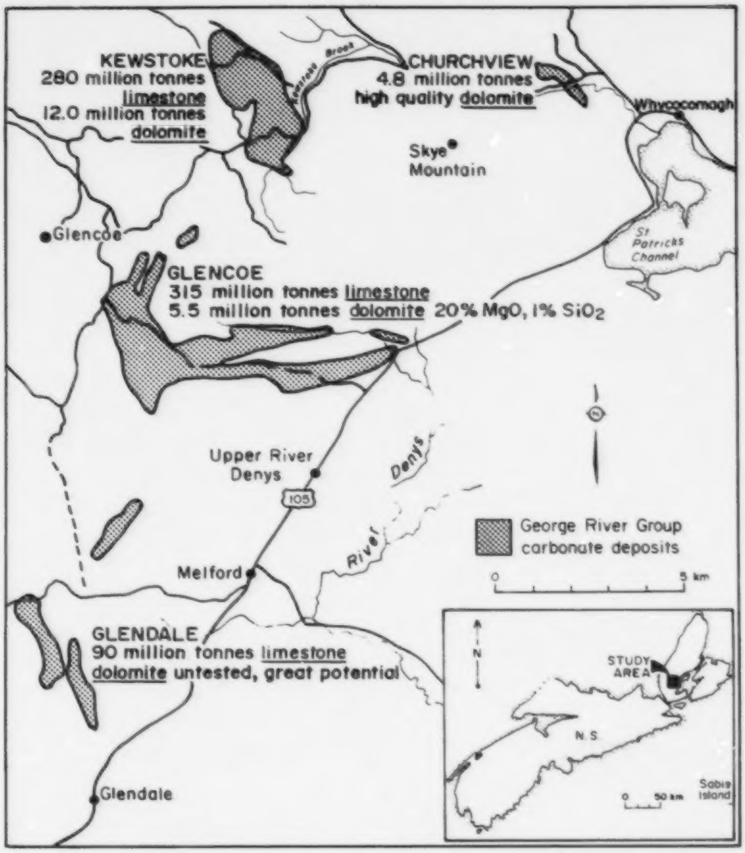

KEWSTOKE
280 million tonnes limestone
12.0 million tonnes dolomite
Kewstoke Brook
CHURCHVIEW
4.8 million tonnes high quality dolomite
Whycocomagh
Skye Mountain
St Patricks Channel
Glencoe
GLENCOE
315 million tonnes limestone
5.5 million tonnes dolomite 20% MgO, 1% SiO2
Upper River Denys
105
River Denys
N
George River Group carbonate deposits
0
5 km
Melford
GLENDALE
90 million tonnes limestone
dolomite untested, great potential
Glendale
N
STUDY AREA
N.S.
Sable Island
0
50 km

Figure 25. Location map showing the major George River Group limestone and dolomite deposits of the Craignish Hills area of Cape Breton Island.

were located within 15 m of holes B-7 and B-8 and intersected only 3-4 m (10-12 ft) of the nearly 50 m (165 ft) thickness of white limestone that was penetrated in the 1976 drillholes. The MgO values changed dramatically from the 3-4% range in the 1976 drillholes to 18-19% in the 1988 drillholes. Although andesite marker beds correspond in both series of drillholes, the carbonate bodies are remarkably different in chemistry.

Another series of five holes (DDHs 88-8, 88-9, 88-10, 88-16 and 88-17) were drilled to infill between lines A and B of the 1976 drilling program. The purpose of these holes was to prove the extension of white limestone beds encountered during the 1976 program to prove a reserve of limestone suitable for fillers, extenders and dimension stone. Very little suitable stone was encountered in these drillholes and this area was also abandoned.

It can be concluded from the diamond drilling program conducted during 1988 that the Glencoe deposit is not only very extensive, but also very complex and a very tight grid of drillholes is necessary in order to obtain a clear picture of the geology necessary to plan a large quarrying operation (MacDonald, 1990a).

Due mainly to the sharp difference in assay results between the 1976 drill program and the 1988 program in the same area along the B line of drillholes, a second assay of drill core and drill core pulps from hole I-3 was conducted during February 1989. Drillhole I-3 was drilled during the 1976 program and is located in the centre of a large block of high CaO/ low MgO stone that is ideally suited and the obvious location for a large quarry of this grade of limestone (see MacNeil, 1977 for exact location). Eight 3 m (10 ft) drill core samples were quartered within the interval between 45 and 152 m (150 and 500 ft) and the original pulps were resampled and submitted for assay at the Minerals Engineering Centre, Technical University of Nova Scotia, in Halifax. Five samples were sent to Lafarge Canada Inc. in Brookfield for comparative analysis (Appendix 2). The results were encouraging because they closely repeat the results of the 1976 program.

Glendale, Inverness County

Another large limestone and dolomite deposit with excellent potential for development is located at Glendale, Inverness County (Figs. 23 and 25) where reserves of 90 Mt of limestone of which 5 Mt are white limestone are estimated (Shaw, personal communication). There is also potentially a large dolomite reserve within the deposit. The Glendale deposit is virtually unexplored. With only one recent, unsuccessful diamond-drill hole completed, most of the information gathered is from surface mapping, sampling and one recent bulk sample test (Shaw, personal communication). Assays of samples collected from outcrops indicate high grade reserves of limestone and dolomite. More exploratory work is required on this deposit to better define the available reserves.

Kewstoke, Inverness County

The limestone deposit located at Kewstoke, Inverness County, is another large George River Group carbonate deposit containing huge reserves of high grade limestone

(Figs. 23 and 25). The area containing the deposit is approximately 3.2 km long in a northwest-southeast direction and from 0.8-1.2 km wide (northeast-southwest). It appears to narrow to the northwest where it is covered by Horton Group sedimentary rocks. The areas underlain by George River Group rocks stand in strong relief and the broader valleys are generally underlain by Horton Group as evidenced along Kewstoke Brook. Two major east-northeasterly striking transcurrent faults break the area underlain by carbonates into three blocks which, for descriptive purposes, were designated the north, central and south blocks by MacNeil (1972).

Reserves have been estimated only for the central block by MacNeil (1977). The central block contains over 280 Mt of cement grade limestone, of which 80 Mt are metallurgical grade limestone. A lense of very pure metallurgical grade dolomite occurs within the sequence on the eastern slope of Kewstoke Hill.

The northern block of the Kewstoke deposit is structurally complex and the lithology is varied; however, the possibility of high quality limestone and dolomite reserves exists and must be further explored by drilling. Similarly, the southern block located south of the Whycocomagh-Port Hood dirt road may contain significant reserves of high quality limestone and dolomite and must be further investigated.

Campbell Brook (River Denys Area), Inverness County

Carbonate units of the George River Group are exposed along Campbell Brook (Fig. 26) which flows northward cutting across the folded sequence of interbedded carbonate and detrital sedimentary rocks. The dominant carbonates are a very pure, massive, calcitic marble, highly hematitic and pervasively cut by calcite and hematite-filled fractures. Interbedded with this unit are numerous varieties of grey, banded, calcitic marbles, thinly foliated, micaceous, calcitic marbles and blue-grey, massive, dolomitic marbles (Hill, 1989).

In 1963, the Nova Scotia Department of Mines drilled a horizontal drillhole through the steeply dipping strata to a distance of 294 m (965 ft) (Fig. 27). Two bands of limestone with possible economic potential were intersected between the intervals 59-78 m (193-255 ft) and 152-255 m (500-837 ft). An average analysis for the two intervals is shown in Table 14.

The Campbell Brook deposit appears to have potential for a large reserve of high quality carbonates based on the surface outcropping and the 1963 drillhole. Additional work in the form of drilling is recommended to better define the reserves and quality of this deposit.

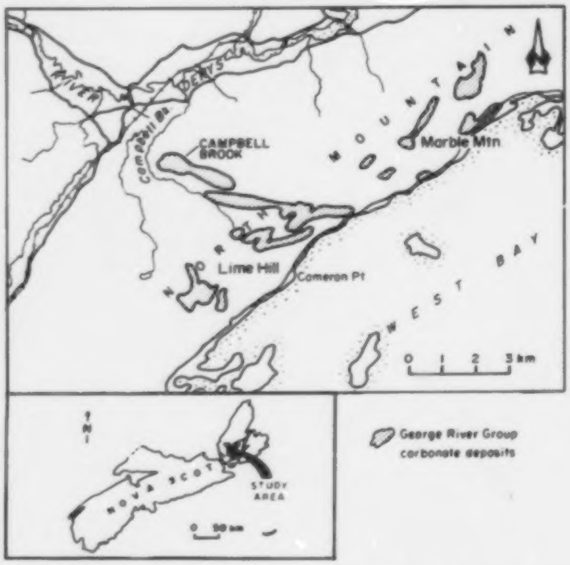

RIVER
DENYS
Campbell Br.
CAMPBELL BROOK
NORTH MOUNTAIN
Marble Mtn
Lime Hill
Cameron Pt
WEST BAY
0 1 2 3 km
N
NOVA SCOTIA
STUDY AREA
0 50 km
George River Group carbonate deposits

Figure 26. Location map showing the George River Group limestone and dolomite deposits of the North Mountain area of Inverness County.

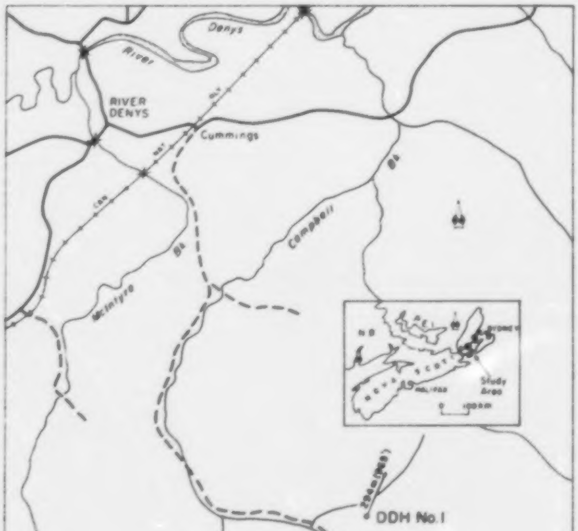

Denys
River
RIVER DENYS
Cummings
Campbell
Bk
McIntyre
Bk
N
NB
PEI
NOVA SCOTIA
Halifax
Study Area
SYDNEY
0 100km
294m (965')
DDH No.1
0 200 400 600 800 1000m
after Milligan, 1970

Figure 27. Location map showing DDH No. 1 drilled horizontally through the George River Group carbonate sequence along Campbell Brook, Inverness County (Nova Scotia Department of Mines, 1963).

Table 14. Average analysis for the two limestone sequences cut by DDH No. 1 at Campbell Brook, Inverness County (Fig. 27).*

Interval	LOI	CaO	MgO	SiO_2	Combined Oxides
59-78 m	42.02	53.45	0.73	3.95	1.09
152-255 m	42.46	46.24	5.15	3.43	1.15

*from Nova Scotia Department of Mines, 1963.

Churchview, Inverness County

A deposit of white, crystalline dolomite of Archean age belonging to the George River Group is located approximately 3.2 km northwest of Whycocomagh at Churchview, Inverness County (Figs. 23 and 25). The dolomite is extremely pure with MgO values of 20% and silica values of 2% (MacDonald, 1990b). It was previously used as a filler in paints in the 1920s by the Brandram-Henderson Paint Company who operated the Quarry shown on Figure 28.

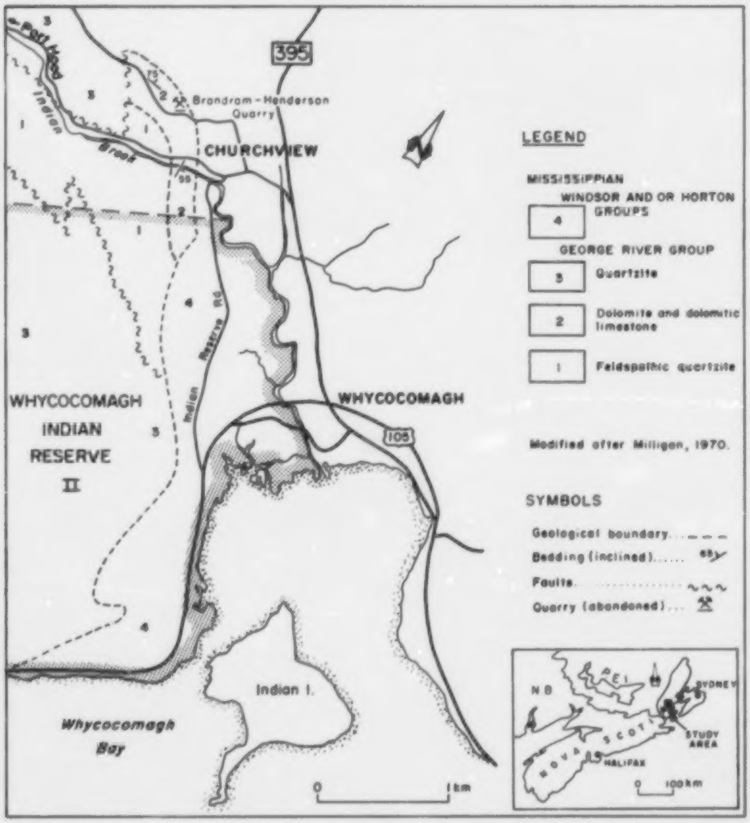

Port Hood
Indian Brook
Brandram-Henderson Quarry
395
CHURCHVIEW
Indian Reserve Rd.
WHYCOCOMAGH INDIAN RESERVE II
WHYCOCOMAGH
105
Indian I.
Whycocomagh Bay
0
1 km
LEGEND
MISSISSIPPIAN
WINDSOR AND OR HORTON GROUPS
4
GEORGE RIVER GROUP
3 Quartzite
2 Dolomite and dolomitic limestone
1 Feldspathic quartzite
Modified after Milligan, 1970.
SYMBOLS
Geological boundary
Bedding (inclined)
Faults
Quarry (abandoned)
N B
P E I
NOVA SCOTIA
SYDNEY
HALIFAX
STUDY AREA
0 100 km

Figure 28. Geology map of the Churchview area of Inverness County showing the George River Group dolomite and dolomitic limestone deposit and the former Brandram-Henderson Quarry.

The dolomite unit has been traced from this abandoned Quarry southeastward approximately 730 m across the Whycocomagh-Port Hood road and Indian Brook (Brigend Brook) and approximately 365 m northwest of the old Quarry where it appears to be truncated along a fault by quartzite (Milligan, 1970). Near the old Quarry the dolomite bed dips from 50-60°E and appears to be 107 m thick. The dolomite bed exposed in Indian Brook is approximately 107 m thick.

The dolomite deposit was surface sampled and three diamond-drill holes completed in 1966 by the Nova Scotia Research Foundation (Shaw, 1975). Based on these data and additional surface sampling and geological mapping, the minable reserve of dolomite is estimated to be 4.8 Mt (Shaw, 1982).

Additional work is justified on this deposit due to its high quality, large reserves and favourable location with respect to road and water transportation.

Kellys Cove, Victoria County

A large reserve of high grade dolomite estimated at 13.6 Mt to sea level has been indicated by a drilling program at Kellys Cove, Victoria County (MacNeil, 1978) (Figs. 23 and 29). The deposit outcrops on deep tidal water and is accessed by an excellent gravel road 6.4 km from the Trans-Canada Highway 105 at New Harris Forks. The deposit is presently being exploited. A new crushing and milling facility has been completed on site and a new docking facility has been constructed adjacent to the operation at Kellys Cove by Mosher Limestone Ltd. The dolomite is presently servicing an agricultural and metallurgical market, but its high quality makes it amenable to many additional uses requiring high grade dolomite.

Glen Morrison, Cape Breton County

Gays River Formation limestone of the Windsor Group occurs along the margin of the Sydney Basin at Glen Morrison, Cape Breton County (Figs. 23 and 30). The Glen Morrison Bank forms a major east-west to northwest-southeast trending outcrop along the northeastern end of the East Bay Hills. The carbonate buildup at Glen Morrison represents the deposits of

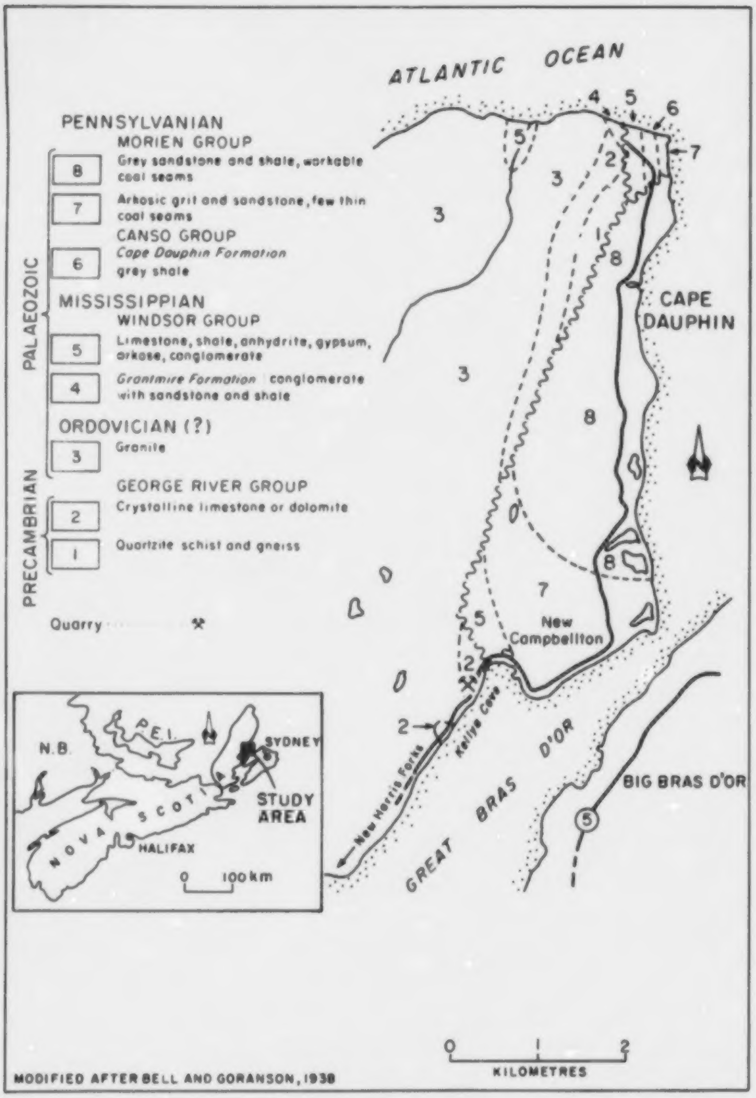

ATLANTIC OCEAN
PENNSYLVANIAN
MORIEN GROUP
8 Grey sandstone and shale, workable coal seams
7 Arkosic grit and sandstone, few thin coal seams
CANSO GROUP
6 Cape Dauphin Formation grey shale
PALAEOZOIC
MISSISSIPPIAN
WINDSOR GROUP
5 Limestone, shale, anhydrite, gypsum, arkose, conglomerate
4 Grantmire Formation conglomerate with sandstone and shale
ORDOVICIAN (?)
3 Granite
PRECAMBRIAN
GEORGE RIVER GROUP
2 Crystalline limestone or dolomite
1 Quartzite schist and gneiss
Quarry
CAPE DAUPHIN
New Campbellton
Kellys Cove
New Harris Forks
GREAT BRAS D'OR
BIG BRAS D'OR
N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
STUDY AREA
HALIFAX
0 100 km
0 1 2
KILOMETRES
MODIFIED AFTER BELL AND GORANSON, 1938

Figure 29. Geology map showing the George River Group limestone and dolomite deposit at Kellys Cove to Cape Dauphin, Victoria County, and also the adjacent Windsor Group limestone and dolomite deposit.

the initial regional mid-Visèan transgression recorded at the base of the Windsor Group (Boehner, 1987). It is underlain by thin Horton Group siliciclastics or unconformably by Hadrynian to Devonian metasedimentary, volcanic or plutonic rocks (Boehner, 1987).

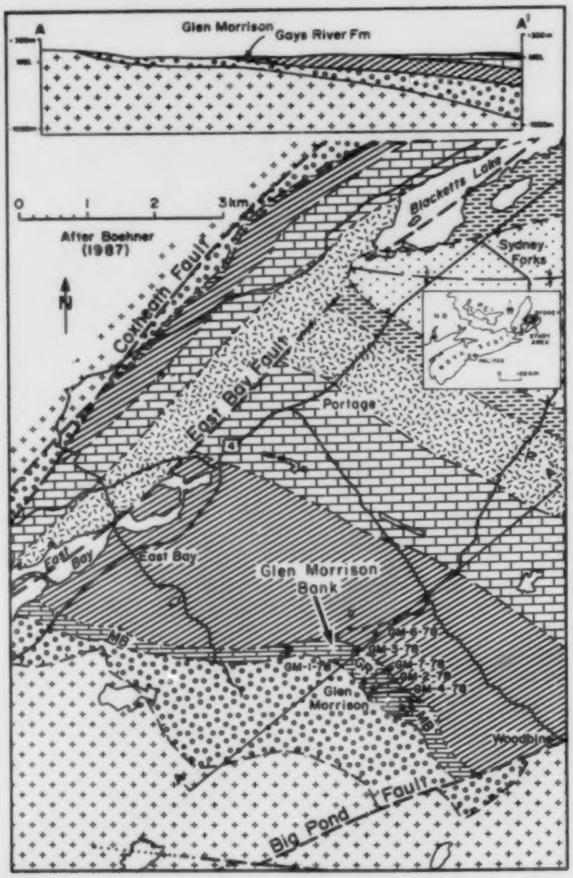
The known limestone bank varies from 200-500 m wide and obtains a maximum thickness of 25.5 m. An estimated limestone reserve of over 3 Mt grading 84.45% $CaCO_3$ was calculated by Kelrock Ltd. (AquaGold Resources Ltd., 1990). During initial sulphation capacity testing by the Nova Scotia Power Corporation, the Glen Morrison limestone has shown to have very good sulphur sorbent capacity therefore making it suitable for use in fluidized bed combustion facilities designed to reduce sulphur emissions resulting from the burning of high sulphur coal (Nova Scotia Power Corporation, personal communication).

Southside Antigonish Harbour, Antigonish County

The Southside Antigonish Harbour (Calpo) deposit (Figs. 23 and 31) contains an estimated 6.3 Mt (Nova Scotia Research Foundation, 1963) of massive, porous, sparsely fossiliferous, high calcium Early Carboniferous Windsor Group limestone (Boehner, 1987). The deposit is presently being mined by Ridge Brokers Ltd. using portable equipment. The limestone is used by a local pulp mill and for local agricultural use.

The deposit is situated on a resistant Early Paleozoic granodiorite knob, with the lower contact an irregular nonconformity with locally steep paleorelief and coarse to fine, reworked, tabs/slump blocks (Boehner, 1987). Caution must be exercised during mining this deposit to prevent these granodiorite blocks from contaminating the limestone. The limestone is overlain to the east by gypsum.

The limestone is extremely high in calcium with silica values consistently <2% and MgO values of <1% (Nova Scotia Research Foundation, 1963). Preliminary testing of this limestone for use in desulphurization fluidized bed combustion of coal indicates that this is the best limestone in the Province for this purpose (Hamer, 1986).


A
Glen Morrison
Gays River Fm
A'
0 1 2 3km
After Boehner (1987)
N
Coxheath Fault
East Bay Fault
Blacketts Lake
Sydney Forks
Portage
4
East Bay
East Bay
Glen Morrison Bank
MB
GM-1-78
GM-6-78
GM-3-78
GM-7-78
GM-2-78
GM-4-78
Glen Morrison
Woodbine
Big Pond Fault

LEGEND

CARBONIFEROUS

⁖ Morien Group
grey sandstone, minor mudstone

☰ Canso Group
grey and minor red mudstone

Windsor Group

▩ *Woodbine Road Formation*
red siliciclastics with thin interbeds of marine carbonates and evaporites

▦ *Meadows Road Formation*
red siliciclastics and evaporites with thin interbeds of marine carbonates

▨ *Sydney River Formation*
evaporite with variable interbedded siliciclastics

▤ *Gays River Formation* (GR) (Glen Morrison Bank)
limestone, thickly bedded, locally highly fossiliferous

MacBeth Brook Formation (MB)
limestone, stromatolitic, and locally shaly

⁘ Horton Group
red siliciclastics

HADRYNIAN to DEVONIAN basement

✚ undivided crystalline rocks

Geological boundary (approximate, assumed) — — - - - -
Fault outline (approximate, assumed) . . . . ━ ━ · · · · ·
Syncline (approximate) . . . . ——┼—
Diamond-drill hole . . . . ● GM-6-78
Unconformity (approximate) . . . . ⊥ ⊥ ⊥ -
Facies boundary (schematic only) . . . . Ƹ

Figure 30. Geology map showing location and structure of the Windsor Group limestone deposit at Glen Morrison, Cape Breton County.

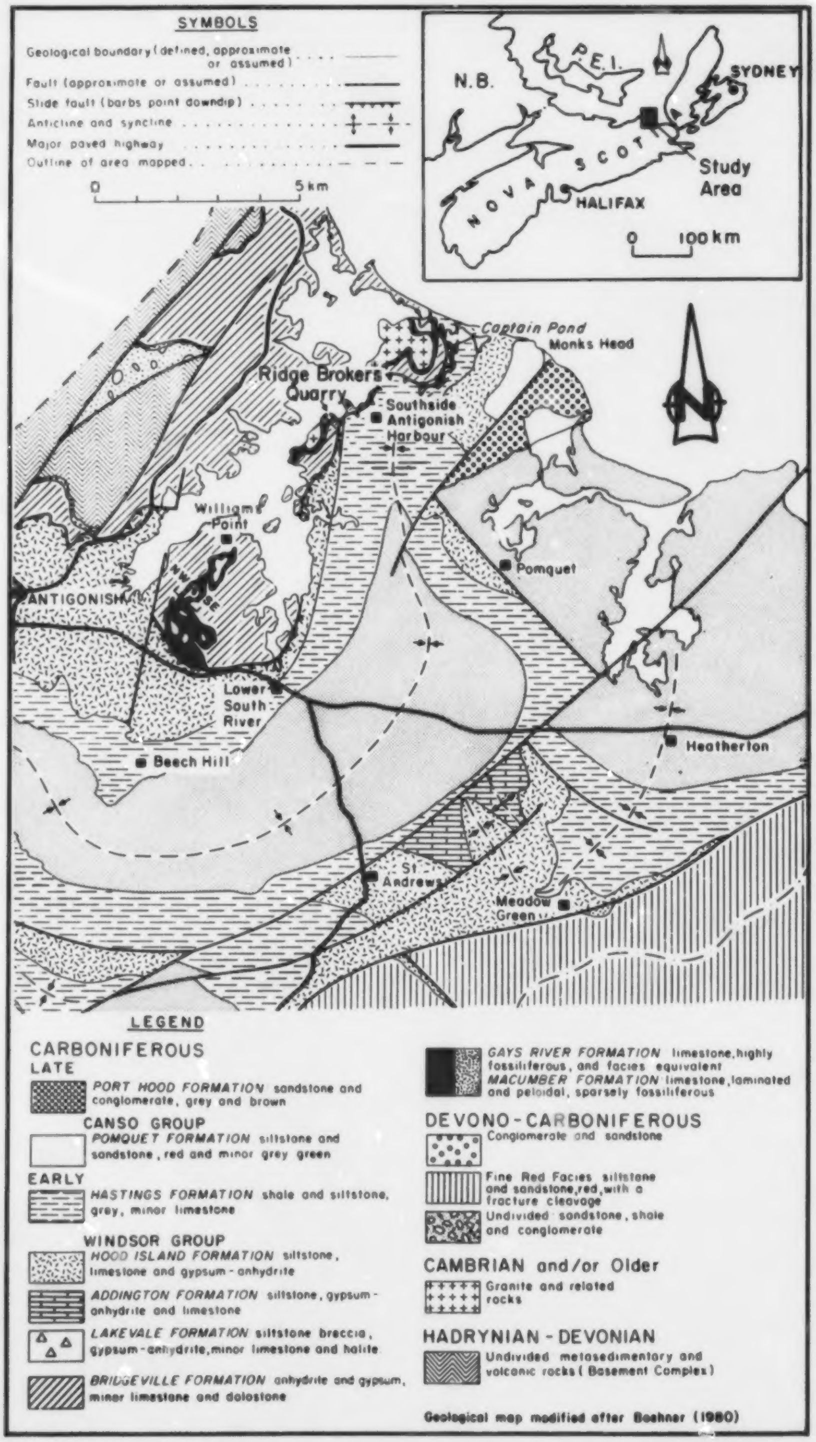

SYMBOLS
Geological boundary (defined, approximate or assumed)
Fault (approximate or assumed)
Slide fault (barbs point downdip)
Anticline and syncline
Major paved highway
Outline of area mapped
0
5 km
N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
Study Area
HALIFAX
0
100 km
Captain Pond
Monks Head
Ridge Brokers Quarry
Southside Antigonish Harbour
Williams Point
ANTIGONISH
Pomquet
Lower South River
Beech Hill
Heatherton
St. Andrews
Meadow Green
LEGEND
CARBONIFEROUS
LATE
PORT HOOD FORMATION sandstone and conglomerate, grey and brown
CANSO GROUP
POMQUET FORMATION siltstone and sandstone, red and minor grey green
EARLY
HASTINGS FORMATION shale and siltstone, grey, minor limestone
WINDSOR GROUP
HOOD ISLAND FORMATION siltstone, limestone and gypsum-anhydrite
ADDINGTON FORMATION siltstone, gypsum-anhydrite and limestone
LAKEVALE FORMATION siltstone breccia, gypsum-anhydrite, minor limestone and halite
BRIDGEVILLE FORMATION anhydrite and gypsum, minor limestone and dolostone
GAYS RIVER FORMATION limestone, highly fossiliferous, and facies equivalent
MACUMBER FORMATION limestone, laminated and peloidal, sparsely fossiliferous
DEVONO-CARBONIFEROUS
Conglomerate and sandstone
Fine Red Facies siltstone and sandstone, red, with a fracture cleavage
Undivided sandstone, shale and conglomerate
CAMBRIAN and/or Older
Granite and related rocks
HADRYNIAN-DEVONIAN
Undivided metasedimentary and volcanic rocks (Basement Complex)
Geological map modified after Boehner (1980)

Figure 31. Geological map of Williams Point-Southside Antigonish Harbour, Antigonish County, showing Ridge Brokers limestone Quarry.

CHAPTER 10. SILICA

Silicon is the most abundant element on the earth's surface and in the form of silica (SiO_2) has a hardness of 7 on Mohs scale, a density of 2.65 and is insoluble in all acids except HF (Berry and Mason, 1959). Silica is usually colourless to white, but can occur in practically any shade.

USES

Silica has many industrial applications in abrasives and polishes, glass manufacture, fillers and extenders, silica brick manufacture, as a catalyst, in specialty coatings, cleansers, ceramics, electronics, optics and refractories, in ferro-silicon manufacture, rubber and as a frac sand (MacDonald, 1991).

Processing silica of specific quality yields several kinds of specialty silicas. These include colloidal, fumed, fused, high purity ground, silica gel and precipitated silica.

Colloidal silica is used mainly as a high temperature binder for silicon wafer polishing and carbonless paper. **Fumed silica**, because of its unique strength, thixotropic properties and flatting properties, is a valuable ingredient in rubber, plastics, cement, specialty coatings, adhesives, sealants, pesticides, cosmetics, pharmaceuticals, defoamers, inks, abrasives and batteries.

Fused silica is produced by fusion of very high quality silica sand feedstock in electric arc and resistance furnaces. The resulting product is very different from the original silica sand due to the extremely high quality, consistent chemistry, high resistance to thermal shock and low thermal conductivity. Fused silica is therefore suitable as a filler for electronic encapsulants, refractory and investment castings and specialty coatings.

High purity ground silica is produced from silica sand or soft, friable rocks and is often referred to as amorphous silica. It is used mainly in specialty coatings, plastics, rubber, electronics, abrasives, refractories and optics depending on average particle size, distribution, hardness and refractive index.

Silica gel is an extremely pure, porous and amorphous form of silica known for a high degree of internal surface area, hardness, uniformity and chemical inertness. Its ability to absorb liquids makes it valuable in a wide variety of applications including catalysts, anticaking agents in food and pharmaceutical products, desiccants, cosmetics, plastics, specialty coatings, paper and adhesives.

Precipitated silica is another kind of specialty silica which is mainly used as a reinforcing agent in tire compounds. Its properties also provide anticaking, conditioning, suspension and viscosity control in products such as toothpastes, deodorants, nail polishes and vitamin tablets.

Current prices for the various forms of these specialty silicas range from $140 (Cdn) per tonne to over $6500 (Cdn) per tonne (Harris et al., 1987).

As expected, world resources of silica are immense with the extremely high grade deposits near markets the most sought after. The future demand for silica products should remain high especially in specialty silica applications. Increased growth in the ceramics industry related to utilizing more ceramic components in automobile engines is one area of expected growth.

NOVA SCOTIA POTENTIAL

Silica occurs both in rock and granular forms. Deposits are common throughout most areas of Nova Scotia. Silica rock occurrences with economic potential are found in quartzites of the Hadrynian George River Group of Cape Breton Island as well as orthoquartzites of the Silurian-Devonian White Rock Formation of southwestern Nova Scotia. Quartz veins with economic potential occur within Cambro-Ordovician Meguma Group rock which comprises 16 317 km^2 of the southern portion of mainland Nova Scotia. High silica content sandstones with economic potential occur in Early Carboniferous Horton Group rocks which occur in central and northern Nova Scotia.

Granular deposits of white silica sand of Cretaceous age occur in Windsor Group fault-bound basins in the Shubenacadie, Musquodoboit and Stewiacke Valleys on mainland Nova Scotia and at Glen Brook (Diogenes Brook, historical name), Inverness County, Cape Breton Island (Dickie, 1986). Other granular deposits are found in isolated sinkholes and unconformity fillings within or adjacent to Windsor Group carbonate rocks, as ice contact deposits throughout the Province and beach deposits along the coast.

Nova Scotia Silica Rock Deposits

There are many occurrences of quartzite throughout Nova Scotia and many grades are available. Quartzite is a metamorphosed sandstone made up chiefly of quartz sand united by a siliceous cement to form hard, low porosity rock. The colour of Nova Scotia quartzite varies from white to grey with a few occurrences tinted various shades of brown, red or yellow due to the presence of small amounts of impurities. There are a few high grade, silica-rich, quartzite deposits in Nova Scotia.

The Chegoggin Point, Yarmouth County, deposit contains minable reserves with SiO_2 percentages as high as >99.0% SiO_2 (Figs. 18, 19 and 32). This deposit occurs in the Silurian-Devonian White Rock Formation and was previously quarried for raw material to manufacture high grade silica brick by Dominion Steel Corporation for use in its steel plant at Sydney, Nova Scotia. During the period from 1947-1963, approximately 100 000 t of silica ore were extracted on a seasonal basis (Taylor, 1967). The ore far exceeded specifications for silica brick manufacture. The deposit consists of wide beds of orthoquartzite contained within a metasedimentary and metavolcanic sequence. The quartzite is fused, extremely hard and has been injected with veins of pure secondary quartz. The beds are lenticular and pinch and swell along strike. A recent diamond-drill hole (Fig. 18) (CH-LG-87-6; MacDonald, 1990d) near the coastline intersected quartzite beds with a total thickness in excess of 61 m. A cross-section of this drillhole is shown in Figure 33. The quartzite beds appear to be discontinuous and displaced at locations along strike. A previous Nova Scotia Department of Mines drillhole (Jones, 1963) intersected similar quartzite beds with a total thickness in excess of 60 m, 16 km northeast on the western shore of Lake George, Yarmouth County. It is estimated that a reserve in excess of 9 Mt of high grade silica occurs in steeply dipping beds of quartzite which extend inland from Chegoggin Point approximately 5 km. Shipping possibilities for this material are enhanced by the availability of 12 m of tidewater at Chegoggin Point. Chemical analysis of this deposit and others appears in Table 15.

Associated with the silica beds and exposed along the coast, are beds of garnet-schist containing 40-50% almandine garnets over widths of 3.5-4.5 m. Preliminary tests indicate the garnets are of excellent abrasive quality and can be concentrated by simple gravity separation (Appendix 1).

Quartzite beds of the White Rock Formation extend intermittently from Chegoggin Point, Yarmouth County, to New Minas, Kings County, a distance of over 200 km. The SiO_2 content of the quartzite is 96-97% at White Rock, Kings County, where the quartzite is quarried and crushed and used to make 'tilt-up' building panels, a popular, modern building technique.

MacDonald (1990d) detailed the exploration, geophysical and drilling programs conducted on the Chegoggin Point-Lake George silica and garnet deposit during this Various Commodities Project.

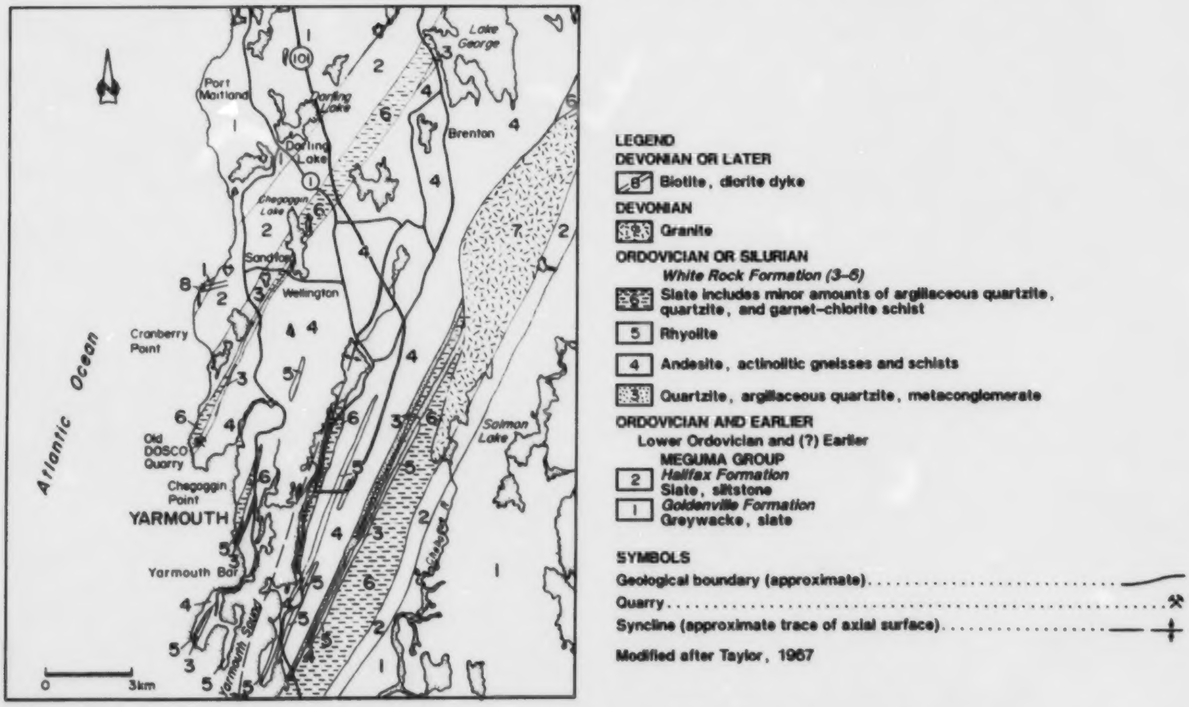

Lake George
Port Maitland
Darling Lake
Brenton
Chegoggin Lake
Sandford
Wellington
Cranberry Point
Atlantic Ocean
Old DOSCO Quarry
Chegoggin Point
YARMOUTH
Yarmouth Bar
Yarmouth Sound
Salmon Lake
101
1
0
3km
1
2
3
4
5
6
7
8
LEGEND
DEVONIAN OR LATER
8 Biotite, diorite dyke
DEVONIAN
7 Granite
ORDOVICIAN OR SILURIAN
White Rock Formation (3–6)
6 Slate includes minor amounts of argillaceous quartzite, quartzite, and garnet–chlorite schist
5 Rhyolite
4 Andesite, actinolitic gneisses and schists
3 Quartzite, argillaceous quartzite, metaconglomerate
ORDOVICIAN AND EARLIER
Lower Ordovician and (?) Earlier
MEGUMA GROUP
2 Halifax Formation Slate, siltstone
1 Goldenville Formation Greywacke, slate
SYMBOLS
Geological boundary (approximate)
Quarry
Syncline (approximate trace of axial surface)
Modified after Taylor, 1967

Figure 32. Geological map for the Chegoggin Point, Lake George, Yarmouth County, area.

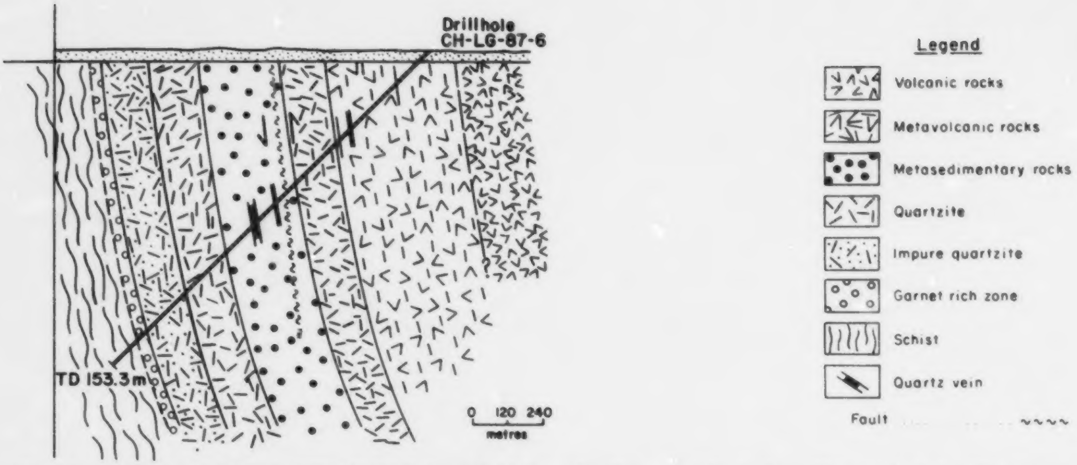

Drillhole
CH-LG-87-6
TD 153.3m
0 120 240
metres
Legend
Volcanic rocks
Metavolcanic rocks
Metasedimentary rocks
Quartzite
Impure quartzite
Garnet rich zone
Schist
Quartz vein
Fault

Figure 33. Cross-section of drillhole CH-LG-87-6 through high grade silica quartzite beds at Chegoggin Point, Yarmouth County. See Figure 18 for location.

Table 15. Chemical analysis of selected, high potential silica deposits throughout Nova Scotia.

					%				
Deposit Location	**Type**	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**MnO**	**S**	**TiO_2**
Chegoggin Point,[1] Yarmouth County	Quartzite (white)	99.70	0.02	0.25	0.012	<0.002	0.002	0.024	n/a
		99.60	0.002	0.35	0.018	<0.002	0.002	0.02	n/a
	Quartzite (dark brown)	98.82	0.38	0.33	0.014	0.007	0.003	0.024	n/a
White Rock Mills,[1] Kings County	Quartzite (white to pale yellow to pale brown)	90.70	0.11	3.24	2.03	2.11	nil	n/a	n/a
		95.01	2.27	1.77	nil	nil	0.13	n/a	n/a
Diogenes Brook,[2] Inverness County	Sand (over 27 m)	96.45	1.27	1.04	n/a	n/a	n/a	0.008	0.12
	Sand (over 18 m)	96.23	1.25	1.17	n/a	n/a	n/a	0.01	0.01
Leitches Creek,[3] Cape Breton County	Quartzite	97.22	1.75	0.40	0.30	0.18	n/a	n/a	n/a
George River,[4] Cape Breton County	Quartzite (average of 7 samples)	96.91	0.66	1.36	0.12	0.27	n/a	n/a	n/a
Aberdeen,[4] Inverness County	Sandstone	96.09	2.15	0.49	0.10	0.38	n/a	n/a	n/a
Skye Mountain,[4] Inverness County	Quartzite	97.37	1.34	0.48	0.12	0.11	n/a	n/a	n/a
Iron Mines,[4] Inverness County	Quartzite	97.66	1.39	0.40	0.10	0.20	n/a	n/a	n/a
Brazil Lake,[5] Hants County	Sand	99.10	0.38	0.14	0.00	0.00	n/a	n/a	n/a
Hantsport,[6] Kings County	Sandstone	96.1	1.83	0.78	n/a	n/a	n/a	n/a	n/a

n/a not applicable.

[1] author; analysis from Minerals Engineering Centre, Technical University of Nova Scotia.

[2] Dickie, 1986.

[3] Goranson, 1931.

[4] Wright, 1964.

[5] Fowler and Stea, 1980.

[6] Goudge, 1952.

On Cape Breton Island, high silica quartzite occurs in the Hadrynian George River Group metasedimentary rocks at Hunters Mountain, Victoria County, and Skye Mountain, Inverness County. A similar silica deposit at Leitches Creek, Cape Breton County, was quarried by the Dominion Steel Corporation in the early 1900s as a source of material for silica brick manufacture for its steel works at nearby Sydney (Fowler, personal communication). The better quality silica ore has been removed from this deposit.

Nova Scotia Silica Sand Deposits

High purity (+98% SiO_2) silica sand suitable for manufacturing glass bottles and fibreglas insulation as well as being suitable as a sandblasting media, occurs in many locations in Nova Scotia. The most notable deposits occur as sinkhole and fault bound Windsor basin fillings in the Musquodoboit and Shubenacadie Valleys and at Glen Brook, Inverness County. Present day silica sand production is from the West Indian Road, Hants County, deposit and from the Elmsdale deposit in the central Musquodoboit Valley. The West Indian Road deposit is a sinkhole filling comprised chiefly of sand and has been producing for many years. The Musquodoboit Valley deposits tend to be lenticular and thin within the Cretaceous section which is comprised of interbedded silica sand and kaolinitic clay (Dickie, 1986).

The silica sand deposit on Glen Brook, Inverness County, is located 3.2 km northwest of the Community of Melford (Fig. 34). Access to the property is provided by a logging road along the western side of Glen Brook from Trans-Canada Highway 105 at Melford, Inverness County. The deposit was worked during the late 1920s by the River Denys Sand and Clay Company, but little evidence of this activity remains (Dickie, 1986).

The silica sand was initially exposed in the stream bed by Glen Brook. The sand is now visible in old and recent excavations near the intersection of the two main tributaries of Glen Brook where up to 20 m thick deposits of ice contact stratified drift occur. The top of the silica sand appears to be flat lying and is approximately 5 m above the present stream level. The sand does not occur as high terraces on either side of the steep stream valley walls and therefore only the top 5 m of the deposit could be removed above the water table.

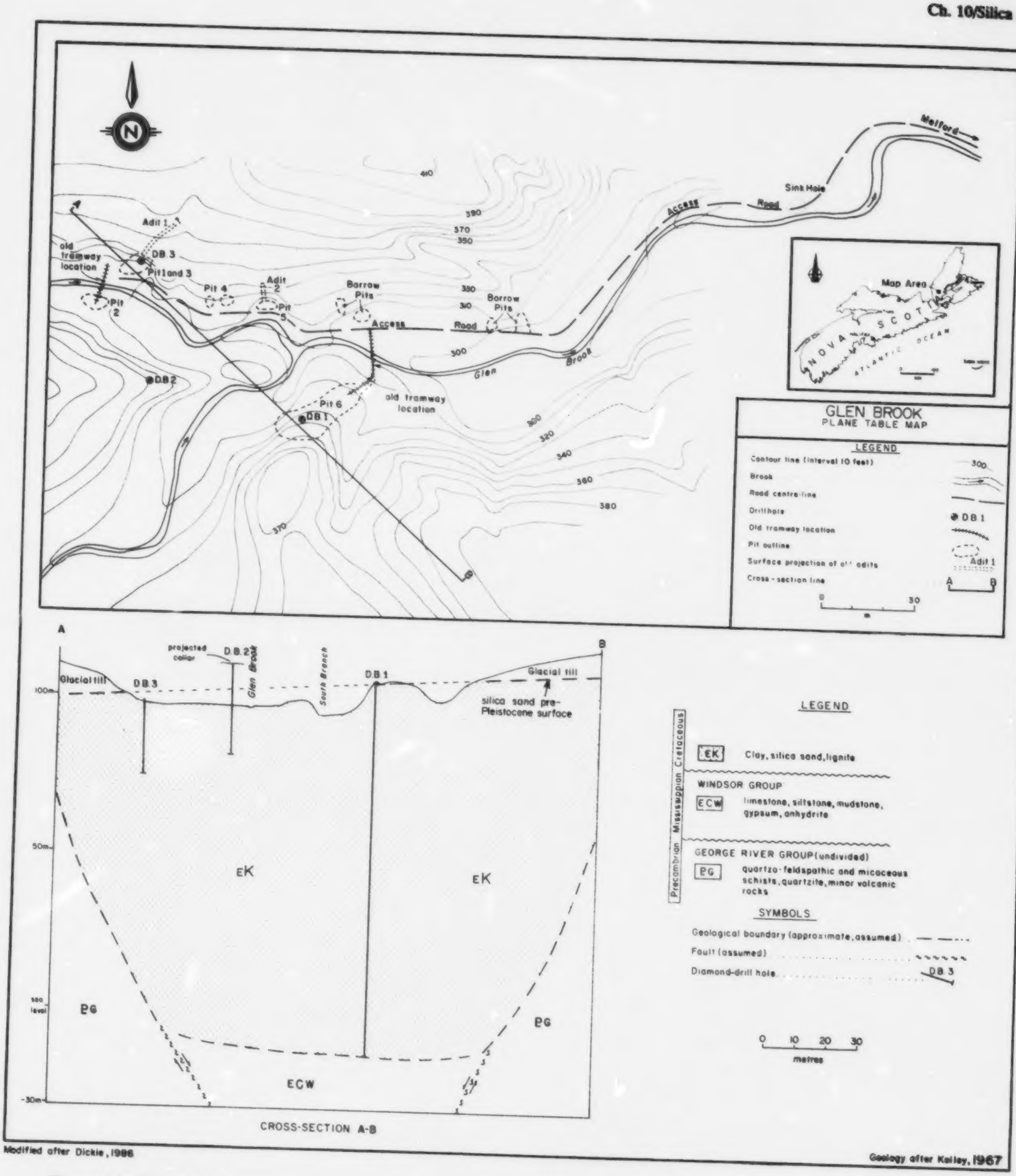
The Nova Scotia Department of Mines and Energy completed three diamond-drill holes on the deposit during 1982 (Dickie, 1986); two to test the overburden thickness and the third drillhole to determine the thickness of the deposit and to retrieve samples for analyses. The deposit consists of interbedded coarse and fine, white sand and clay. It is 125 m thick and overlies a white limestone breccia. At the surface, the bedding planes strike 180° and dip 40° east (Fig. 34). Analysis of the sand samples collected during the drilling program indicated that a possible 7 Mt of >95% SiO_2 are in situ at, and mostly under, Glen Brook (Dickie, 1986).

Nova Scotia Quartz Veins

Quartz is the most common mineral in Nova Scotia's gold districts making up 20-30% by volume in some deposits. The quartz veins reach widths in excess of 6 m at certain locations and are extremely high grade, massive, colourless to white and range from semitransparent to opaque. Wide quartz veins of this type are known to occur within the Meguma Group Terrane in southwestern Nova Scotia at Little Tobeatic Lake, Shelburne County, and Flintstone Rock, Yarmouth County (Fig. 35). They also occur near Country Harbour, Guysborough County, (Fig. 36) where SiO_2 values in the veins are in the 98-99% range. Quartz veins are common throughout the Meguma Terrane.

Nova Scotia High Silica Sandstone Deposits

High silica sandstone deposits are found in Early Carboniferous rocks of the Horton Group. The deposit with the best potential for development is located just west of Hantsport, Kings County (Fig. 37). Previous diamond drilling indicated a reserve of 100 000 t grading 96.1% silica (Goudge, 1952). Other known Horton Group silica-rich deposits of quartz arenite with SiO_2 percentages in the 83-90% range are located near Willowdale, McKinnon Lake and Lansdowne Station in Pictou County and near Sutherland Brook, Colchester County (Fig. 38).


N
Melford
Sink Hole
Access Road
410
390
370
350
330
310
300
Adit 1
old tramway location
DB 3
Pit 1 and 3
Pit 4
Adit 2
Pit 5
Pit 2
Borrow Pits
Borrow Pits
Access Road
Glen Brook
DB 2
Pit 6
DB 1
old tramway location
300
320
340
360
380
370
A
B
Map Area
NOVA SCOTIA
ATLANTIC OCEAN
GLEN BROOK
PLANE TABLE MAP
LEGEND
Contour line (interval 10 feet)
300
Brook
Road centre-line
Drillhole
DB 1
Old tramway location
Pit outline
Surface projection of old adits
Adit 1
Cross - section line
A B
0 30
m
A
B
projected collar
D.B.2
Glen Brook
South Branch
D.B 1
DB 3
Glacial till
Glacial till
100m
silica sand pre-Pleistocene surface
50m
sea level
-30m
EK
EK
PG
PG
ECW
CROSS-SECTION A-B
LEGEND
Precambrian
Mississippian
Cretaceous
EK
Clay, silica sand, lignite
WINDSOR GROUP
ECW
limestone, siltstone, mudstone, gypsum, anhydrite
GEORGE RIVER GROUP (undivided)
PG
quartzo-feldspathic and micaceous schists, quartzite, minor volcanic rocks
SYMBOLS
Geological boundary (approximate, assumed)
Fault (assumed)
Diamond-drill hole
DB 3
0 10 20 30
metres

Modified after Dickie, 1986

Geology after Kelley, 1967

Figure 34. Plane table map and cross-section of Glen Brook (Diogenes Brook), Inverness County, silica sand deposit.

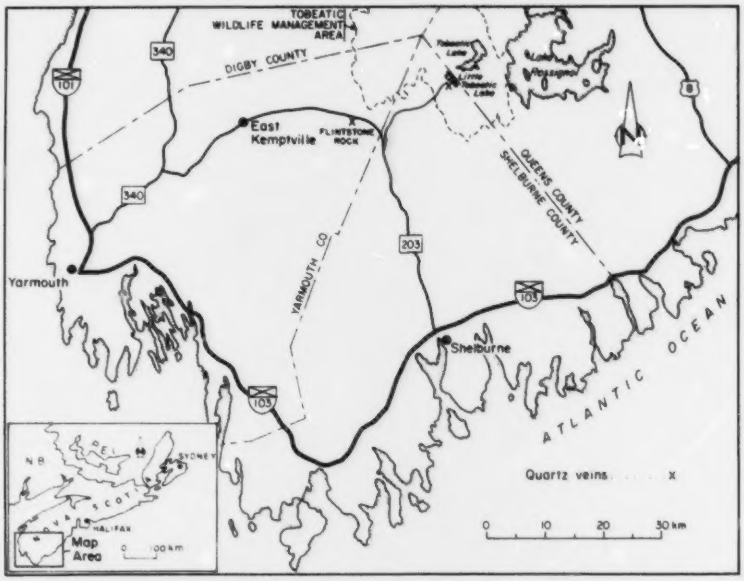

TOBEATIC WILDLIFE MANAGEMENT AREA
DIGBY COUNTY
340
101
East Kemptville
FLINTSTONE ROCK
Little Tobeatic Lake
QUEENS COUNTY
SHELBURNE COUNTY
8
340
203
YARMOUTH CO
Yarmouth
103
Shelburne
103
ATLANTIC OCEAN
Quartz veins X
0 10 20 30 km
N B
P E I
SYDNEY
NOVA SCOTIA
HALIFAX
Map Area
0 100 km

Figure 35. Map showing location of wide quartz veins at Flintstone Rock, Yarmouth County, and Little Tobeatic Lake, Shelburne County.

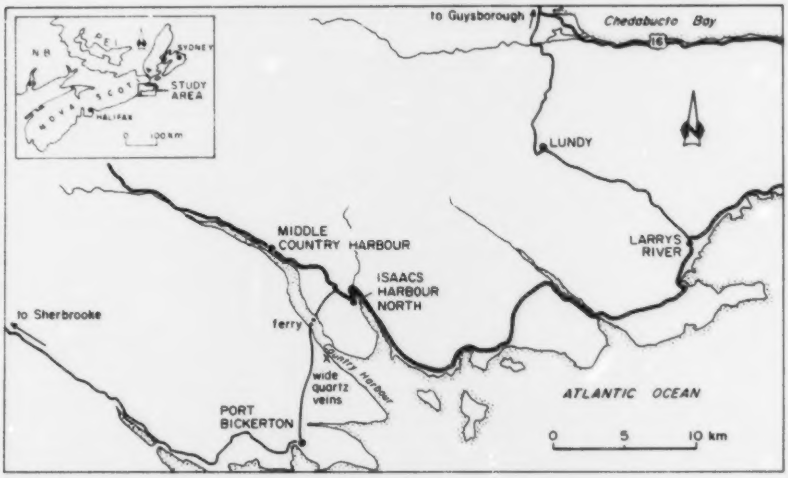

to Guysborough
Chedabucto Bay
16
N B
P E I
SYDNEY
NOVA SCOTIA
STUDY AREA
HALIFAX
0 100 km
LUNDY
MIDDLE COUNTRY HARBOUR
LARRYS RIVER
ISAACS HARBOUR NORTH
to Sherbrooke
ferry
Country Harbour
wide quartz veins
PORT BICKERTON
ATLANTIC OCEAN
0 5 10 km

Figure 36. Location map showing area of wide quartz veins near Country Harbour, Guysborough County.

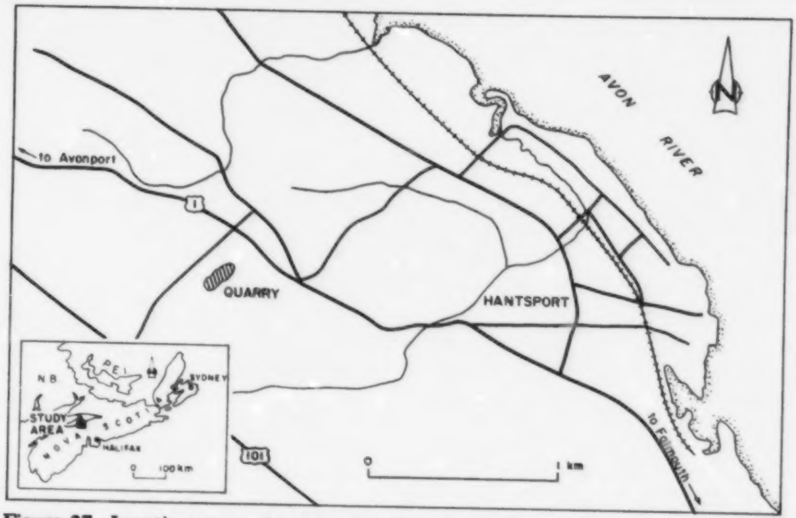

AVON
RIVER
to Avonport
1
QUARRY
HANTSPORT
101
to Falmouth
0
1 km
N.B.
P.E.I.
SYDNEY
STUDY AREA
NOVA SCOTIA
HALIFAX
0 100 km

Figure 37. Location map showing old silica sandstone quarry and deposit near Hantsport, Hants County, where a proven reserve of 100 000 t grading 96.1% silica has been delineated by Goudge (1952).

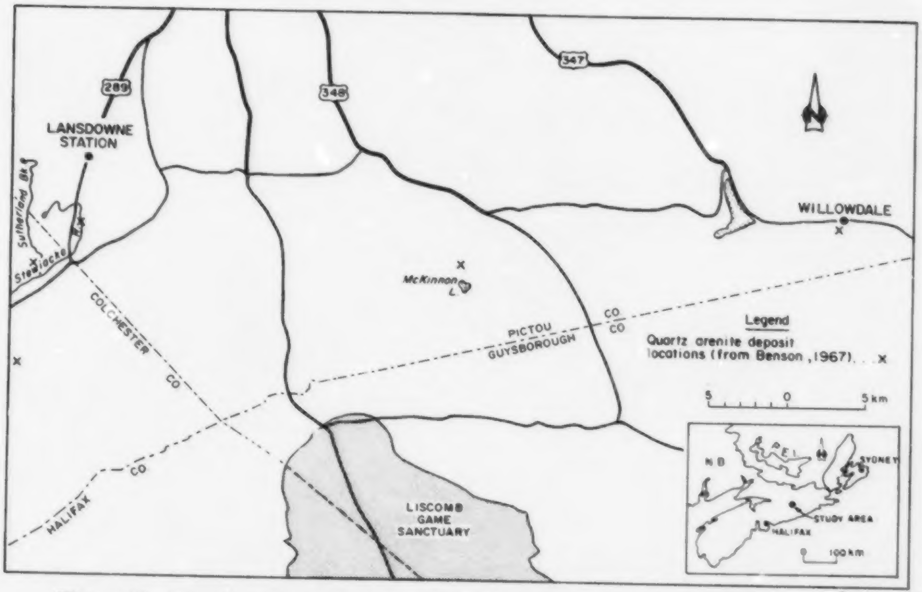

289
348
347
LANSDOWNE STATION
Sutherland Bk
Stewiacke R
WILLOWDALE
McKinnon L
COLCHESTER CO
PICTOU CO
GUYSBOROUGH CO
HALIFAX CO
LISCOMB GAME SANCTUARY
Legend
Quartz arenite deposit locations (from Benson, 1967). . . x
5 0 5 km
N.B.
P.E.I.
SYDNEY
STUDY AREA
HALIFAX
0 100 km

Figure 38. Location map showing silica-rich deposits of quartz arenite near Willowdale, McKinnon Lake and Lansdowne Station, Pictou County, and near Sutherland Brook, Colchester County.

CHAPTER 11. SPODUMENE

Spodumene is an aluminous lithium (alkali) silicate but, unlike the other pyroxenes, is not subject to wide variations in composition as a result of atomic substitutions. Its chemical formula is $LiAlSi_2O_6$ with partial substitution of sodium for lithium. Spodumene is colourless, greyish white or white and sometimes pale or lilac (kunzite). It has a density of 3.1-3.2 and a hardness of 6.5 on Mohs scale (Berry and Mason, 1959).

USES

The aluminum, ceramics, glass, lubricating grease and synthetic rubber industries are the major consumers of lithium minerals and chemicals. Lithium glasses, glazes and enamels have many special and superior characteristics. Lithium greases have superior temperature-viscosity characteristics and have good resistance to water, oxidation and hardening. Other common applications are in electrolytes of alkaline storage batteries, in air-conditioning and refrigeration systems, as fluxes in nonferrous welding and brazing, in paint manufacture, in dyes, in the synthesis of some pharmaceutical products and in lens coatings.

NOVA SCOTIA POTENTIAL

The only significant deposit of spodumene discovered to date in Nova Scotia occurs at Brazil Lake, Yarmouth County (Fig. 39). Two parallel sills (or dykes) of pegmatite intruded the metavolcanic rocks and quartzites of the White Rock Formation. The pegmatites are associated with the Devonian granitic rocks which form the nearby Brenton Pluton.

The outcrop is located approximately 760 m southeast of the Brazil Lake crossroads along the Brazil Lake-Pleasant Valley road. Neither the length nor the thickness of the pegmatites is known accurately. The eastern one is exposed for 21 m parallel to the regional trend and 6 m normal to it. The western pegmatite is at least 10 m thick at the northern exposed outcrop and is assumed to exceed 97 m in length (Taylor, 1967).

The minerals comprising the pegmatites in decreasing abundance are feldspar, quartz, spodumene, muscovite, beryl, tourmaline, biotite and apatite (Walsh, 1971).

A modal analysis of the western outcrop with points on 0.3 m centres is shown in Table 16 (Walsh, 1971).

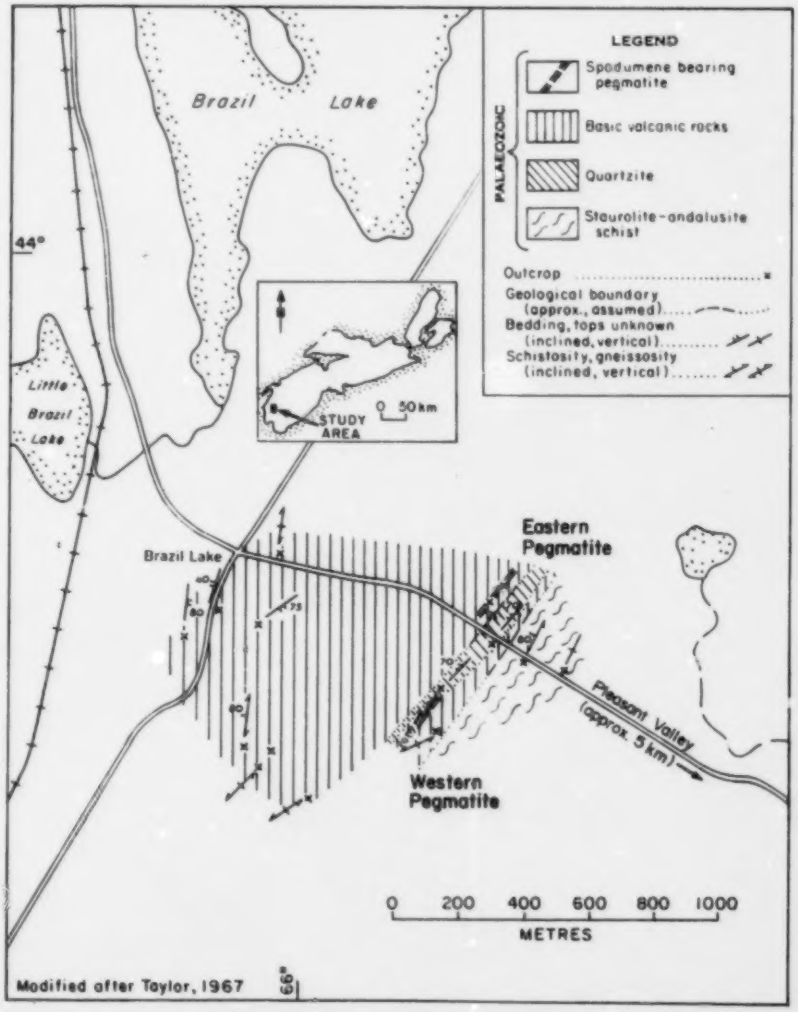

LEGEND
PALAEOZOIC
Spodumene bearing pegmatite
Basic volcanic rocks
Quartzite
Staurolite-andalusite schist
Outcrop
Geological boundary (approx., assumed)
Bedding, tops unknown (inclined, vertical)
Schistosity, gneissosity (inclined, vertical)
Brazil Lake
Little Brazil Lake
44°
STUDY AREA
0 50km
Brazil Lake
Eastern Pegmatite
Western Pegmatite
Pleasant Valley (approx. 5 km)
0 200 400 600 800 1000
METRES
66°
Modified after Taylor, 1967

Figure 39. Location map showing spodumene bearing pegmatite 760 m southeast along the Pleasant Valley road from the Brazil Lake crossroads, Yarmouth County.

Table 16. Modal analysis of western outcrop of spodumene bearing pegmatite at Brazil Lake, Yarmouth County, with points on 0.3 m centres showing the mineral content.*

feldspar (mainly white plagioclase)	52.4%
quartz	34.0%
spodumene	10.7%
mica (chiefly muscovite)	2.6%
beryl	0.5%
Total	100.2%

*from Walsh, 1971.

The Brazil Lake deposit is ideally located on an excellent roadway, within 1.5 km of railroad and within 32 km of the seaport of Yarmouth.

The major concern with the deposit is the size of the reserve. The largest consumer would be the United States ceramics industry and competition would be strong since there are a few long established United States producers with very large reserves.

Byproducts such as mica, quartz, beryl and feldspar may improve the economic feasibility of mining this deposit, but the same oversupply of these commodities on the market place would lead to strong competition.

If a suitable reserve could be proven, then perhaps using the spodumene to produce a basic lithium chemical would improve the market picture and create a local secondary industry as well.

CHAPTER 12. TALC AND PYROPHYLLITE

Talc is an acid metasilicate of magnesium with the chemical formula $Mg_3Si_4O_{10}(OH)_2$ with silica comprising 63.5%, magnesium 31.7% and water 4.8%. It has a greenish, whitish or grey colour (Berry and Mason, 1959). It is derived from the alteration of pyroxene, amphibole, enstatite, tremolite and other magnesium silicates and is often found associated with dolomite, serpentine, quartz or magnesite. Talc exhibits a pearly lustre, has a specific gravity of 2.7 and is greasy to the touch.

Pyrophyllite is an acid, hydrous metasilicate of alumina having the chemical formula $Al_2Si_4O_{10}(OH)_2$. It is white to pale yellow and often stained reddish or brown by iron oxides. It occurs in low- to medium-grade metamorphic rocks rich in aluminum. Pyrophyllite has a pearly lustre on cleavage surfaces, otherwise it exhibits a greasy or dull lustre. It has a specific gravity of 2.84 and a hardness of 1-1.5 on Mohs scale. Its physical properties are practically identical to those of talc and, for this reason, pyrophyllite finds industrial uses similar to talc.

USES AND SPECIFICATIONS

Talc is used mainly in a fine ground form and has many industrial applications. In pulp and paper manufacture softness, chemical inertness, high reflectance, hydrophobic and organophilic properties and the particle shape of talc are characteristics that permit its use as a pitch-absorbing agent, as a paper filler and as a coating pigment.

The ceramic industry uses very finely ground talc to increase the translucence and toughness of the finished product and to aid in promoting crack-free glazing. The talc used must be low in iron, manganese and other impurities which would discolour the fired product. In plastics, talc improves dimensional stability, chemical and heat resistances, impact and tensile strengths, electrical and insulation properties. It is used in thermoplastics and in thermosets, mainly in polypropylene, nylon and polyester. Chemical coupling agents are used to enhance the bond between the talc filler and the resin matrix in plastic materials. The talc must be free of iron impurities and grits and be sized superfine.

High quality talc is used as an extender pigment in paints. The talc must be of acceptable chemical composition, colour, particle size, oil absorbency and fineness of dispersion as established by the industry. Paint characteristics influenced by the use of talc as an extender are gloss, adhesion, flow, hardness and hiding power. Pharmaceutical industries use high purity talc for pharmaceutical preparations and cosmetics, relying on its softness, hydrophobic property and chemical inertness. Finely ground, it is used as a filler in tablets and as an additive in medical pastes, creams and soaps.

Lower grade talc is used as a dusting agent for asphalt roofing and rubber products, as a filler in drywall sealing compounds, floor tiles, asphalt, pipeline enamels, autobody patching compounds and as a carrier for insecticides. Other applications for talc include use in cleaning compounds, polishes, electric cable coating, foundry facings, adhesives, linoleum, textiles and in the food industry.

As previously stated, pyrophyllite can be ground and used in many of the same applications as talc. In ceramics, it imparts a very low coefficient of thermal expansion to tiles. It must be sized -325 mesh and contain a minimum of quartz and sericite which are common impurities. It may also be used in refractories as its expansion on heating tends to counteract the shrinkage of the plastic fraction.

NOVA SCOTIA POTENTIAL

Several occurrences of talc and pyrophyllite in Nova Scotia are mentioned in various reports on file with the Nova Scotia Department of Natural Resources. They are at Soapstone Mine on Indian River (Brigend Brook, local name) near Whycocomagh in Inverness County; near Kennington Cove (Landing Cove) and Eagles Head approximately 6.5 km southwest of Louisbourg in Cape Breton County; at depth in the former Mindamar Mine at Stirling, Cape Breton County; east of Georgeville in Antigonish County; and at the Scotch Lake Quarry near Georges River in Cape Breton County (Fig. 40).

Soapstone Mine, Inverness County

The talc occurrences are located approximately 5 km northwest of Whycocomagh along the Port Hood road near an abandoned steel bridge. In 1896, it was reported that three pits were worked for talc (Goudge, 1943). Pit No. 1 (Pit A) (Fig. 41) was located on the southern edge of the highway "300 yards northwest of S. L. Fraser's sawmill on Brigend Brook" (Goudge, 1943). The pit was between 15-20 m deep, but several tonnes of talc were extracted and shipped to Pictou for grinding (Goudge, 1943). The pit has been filled in over the years due to reconstruction of the roadway and today there is no evidence of it. A second pit (Pit B) was located about 90 m north of the road up a small brook flowing into

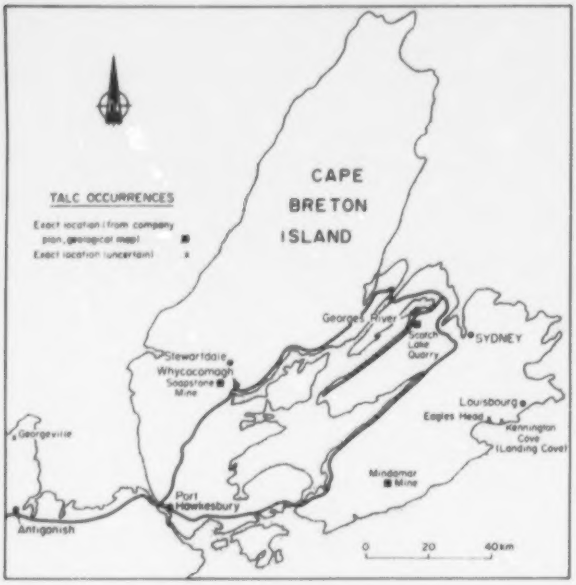


Figure 40. Location map showing occurrences of talc and pyrophyllite within Nova Scotia which are documented with the Nova Scotia Department of Natural Resources.

Indian River. It was reported to be 12-15 m deep, but there is no record of any talc being extracted from it. It was located in 1943 by Spence and his examination of the waste pile resulted in his stating "the material is of no commercial or strategic interest" (Spence, 1943). One or two other pits have been reported in earlier records, one was about 12 m west of Pit A and another (Pit C) was about 0.5 km northeast of Pit A (Spence, 1943). All traces of these pits have disappeared.

The following is taken from a report by Spence (1943) describing the talc taken from two of these pits:

RESULT OF DETAILED EXAMINATION OF TALC SAMPLES

About a dozen pieces of rock, in part showing strong evidence of some talc content, were collected as a sample at pits No. 1 and 3, as indicated in the above report, and these were given microscopic and other examination, with the following results.

Pit No. 1 (Pit A; Fig. 41)

The bulk of the material from this opening proved to consist of banded, greyish-white to buff, medium- to rather fine-grained dolomitic limestone. Some pieces were distinctly quartzose, with the silica in the form either of grains or thin seams. In a few cases, the rock was in part ferruginous, with zones pitted with small cavities containing red iron rust probably derived from the oxidation of pyrite.

Nearly every piece gave active effervescence with cold hydrochloric acid dropped on the surface.

Only a few small pieces, up to 2 ins. across, consisted entirely of clean talc. These showed talc of modified steatitic character, soft, composed of compact aggregate or fine flakes, and of a grey "mutton-fat" colour. Such material proved to be penetrated by numerous random slickensided joints, such as would be produced by squeezing, and is probably not solid or massive enough to be of lava quality.

A number of pieces of dolomite limestone were found to be banded with thin layers or seams of fine, flake talc that could be peeled off as paper-thin, fissile sheets. Several wedge-shaped pieces that externally showed only talc proved to consist of a core of talcose dolomite limestone carrying only a thin skin of talc.

While the above material cannot, of course, be regarded as representative of what may have been found in the opening, it indicates the character of the occurrence as a banded formation of quartzite and dolomitic limestone, the latter containing thin seams of squeezed, compact or finely foliated talc. It is doubtful if a deposit of this nature can be expected to yield talc of lava quality.

Pit No. 3 (Pit B; Fig. 41)

Practically all of the rock collected from this opening proved to consist of a banded, greenish-grey, talcose dolomitic limestone, with the talc in the form of small- to medium-sized flakes averaging 1/2 to 1 in. across.

While all of the rock carries some disseminated talc, the latter tends to be concentrated as thin layers on bedding or squeeze planes and seams. No talc approaching steatitic character was seen.

The average talc content of the rock is not estimated to be over 10 per cent.

In one piece, considerable pyrite was present, in the form of minute, scattered crystals, and some of the rock showed small nests of green chlorite flakes.

"Hugh S. Spence"
Industrial Minerals Division
Bureau of Mines, Ottawa
November 15, 1943.

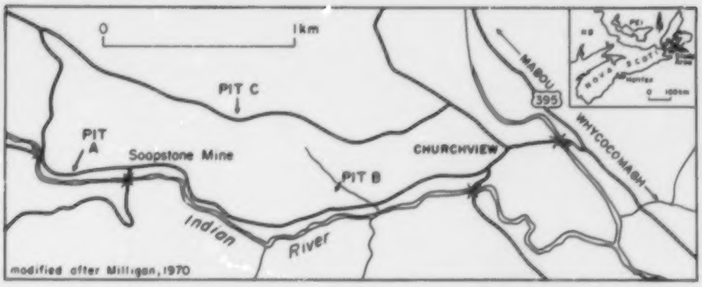


Figure 41. Location map showing talc pits described by Spence (1943) near Whycocomagh, Inverness County.

As part of the Various Commodities Project 1986 field season, a field visit was made to the Soapstone Mine-Indian River talc deposit. An attempt was made to locate the old pits described in the old reports. The evidence of what appears to be old workings (Pit A, Fig. 41) were located along the Port Hood highway west of the old iron bridge. An outcrop along strike on the opposite side of Indian River was sampled. The outcrop appeared to be a siliceous dolomite, greyish white with greenish white sections that were softer and greasy to touch. The sample was first acid leached (14.53% loss) and then assayed for MgO (29.33%) and SiO_2 (68.8%) percentage.

The results are close to the percentages for SiO_2 and MgO content of talc given earlier in this report, but the talc sample appears hard and very impure containing abundant silica and dolomite. The sample examined during this project appears to very closely resemble the description offered by Spence (1943) included above as "a banded formation of quartzite and dolomitic limestone, the latter containing thin seams of squeezed, compact or finely foliated talc". Spence's (1943) conclusion that this deposit will unlikely yield an economic source of talc must be supported here as well.

Kennington Cove (Landing Cove) and Eagles Head, Cape Breton County

Occurrences of talc-like material have been recorded along Gabarus Bay at Kennington Cove (Landing Cove) and Eagles Head (Fig. 40). A report by Church (*in* Messervey, 1926) discussed the deposit at Landing Cove. He described the material in the vein as a silicate of alumina, making it pyrophyllite or sericite. This was supported by sampling and assaying completed by the author in 1986. However, the analysis given by Church's report is misleading and quite likely erroneous as it indicates a silicate of magnesia or talc (Messervey, 1926).

A critical problem regarding the development of the Landing Cove deposit is its position within the boundaries of the Fortress of Louisbourg National Park. This is the actual site where General Wolfe and the combined British and American forces made their landing when Louisbourg was captured in 1745. It is unlikely that any development will occur on this deposit.

Other occurrences along Gabarus Bay (i.e. Eagles Head) are small and virtually unexplored for pyrophyllite and talc, but may contain reserves similar to what appears to occur at Landing Cove.

Stirling, Cape Breton County

Talc was encountered in the former Mindamar Mine at Stirling, Cape Breton County (Fig. 40). The Mindamar Mine was active until 1956 and during its life, and previous operators, produced approximately 1 Mt of ore averaging 6.4% Zn, 1.5% Pb, 0.74% Cu with Ag and Au contents of 2.2 oz and 0.03 oz per ton respectively (Messervey, 1965). Along what is referred to as the mine shear (a shear plane containing the ore [illegible] formed by the same forces which formed the much larger regional Stirling Fault), a number of zones of talc or sericite have replaced the original rock and host the sulphides. The talc is fine grained, massive, white to green and translucent in places. A sample collected from the mine dump in 1986 assayed 26.80% MgO, 25.89% SiO_2, 3.03% H_2O and 28.00% LOI.

The talc is impure containing sulphides, carbonates, and minor feldspar and quartz. Further testing is needed to determine what market, if any, the talc would fulfil. The economic recovery of the talc would only be feasible as a secondary product resulting from the mining of the remaining sulphide ore body.

In 1989, I. M. D. Laboratories Ltd. undertook a processing study on drillcore containing intersected intervals of Stirling talc ore (Hunter, 1989). The test was only partially successful. A talc product can be extracted by flotation, but the product has several negative factors including questionable grade and sulphide minerals floated with the talc. Additional metallurgical work is recommended using a larger bulk sample of ore. Further work on the deposit is recommended in order to determine if ore reserves and product purity are present to give an economical 30-40% product yield (Hunter, 1989).

Georgeville, Antigonish County, and Scotch Lake Quarry, Cape Breton County

Two other occurrences of talc were mentioned by Fletcher and Faribault (1887) and were investigated in 1986. One is just east of Georgeville in Antigonish County where talc is associated with serpentine in a narrow quartz vein imbedded with black slates and sandstones. A second occurrence is at the Scotch Lake Quarry, Cape Breton County, where thin layers of talc are found along some shear zones in the serpentinized dolomite (Fig. 40). Neither occurrence is an economically feasible source of talc.

CHAPTER 13. TITANIUM

Titanium (TiO_2) occurs in three polymorphous forms, of which rutile is by far the most common in nature.

The mineral is formed at high temperatures and is a widespread accessory mineral in igneous rocks, gneisses and schists. It is also found in pegmatites, in metamorphosed limestones, quartzites and in high temperature veins with apatite or quartz. It is also common in sands formed along beaches and river beds.

The major producing country in 1986 of natural rutile (95-96% TiO_2) was Australia which had the capacity to produce 56% of the total world production of 487 000 t. Most of the Australian rutile production comes from mineral sand deposits. Australia also has the capacity to produce 48% of the world's production (1986) of approximately 3.3 Mt of ilmenite (44-63% TiO_2) (Clarke, 1986).

Outside Australia, three new projects are poised to come onstream to meet the demands of the recent titanium minerals boom. In Norway, a new titanium dioxide slag operation will produce 200 000 tpa of 75% TiO_2 slag. In India a new 100 000 tpa synthetic rutile plant will produce 92% TiO_2 chiefly for export, and in Brazil a new facility will introduce anatase ($4(TiO_2)$) as a major, natural titanium mineral feedstock aimed at the pigment industry. In total these three countries will add 200 000 tpa of 75% TiO_2 slag, 100 000 tpa of 92-93% TiO_2 synthetic rutile, [illegible]0 000 tpa 95-96% TiO_2 rutile and 400 000 tpa of 90-91% TiO_2 anatase to the market (Clarke, 1986).

USES

Perhaps the most important use for titanium is in the aerospace industry which consumes about 75% of the rod and bar forms. Titanium represents about 6% of the empty weight of today's large commercial aircraft. For aircraft and space use, there is essentially no substitute for titanium's high strength, toughness, heat resistance and high structural efficiency. Titanium's superior resistance to corrosion is another characteristic of titanium valued in the aerospace industry as well as other industrial uses such as surface condensers in power plants, heat exchangers and chemical industry equipment.

In the pigment industry, consumption of TiO_2 pigments continues to reach new levels mainly because of continued expansion in the home building industry. United States distribution of titanium pigment shipments, titanium dioxide content, by industry for the five year period from 1982-1986 is shown in Table 17.

Table 17. United States distribution of titanium pigment shipments, titanium dioxide content, by industry for the five year period from 1982-1986.*

	Per Cent				
Industry	1982	1983	1984	1985	1986
Paint, varnish, lacquer	48.1	48.9	54.8	54.3	52.6
Paper	27.4	27.3	19.9	20.5	20.7
Plastics (except floor covering and vinyl-coated fabrics and textiles)	12.7	13.2	15.4	16.2	15.8
Ceramics	1.2	1.0	1.0	0.7	2.2
Rubber	2.6	1.8	2.0	1.7	2.0
Printing ink	1.0	1.1	1.2	1.0	1.4
Other	7.0	6.7	5.7	5.6	5.3
Total	100.0	100.0	100.0	100.0	100.0

*from Lynd and Hough, 1986.

World production and demand for TiO_2 pigments remain at record high levels, estimated at 2.6 Mt in 1986. Prices of concentrates and pigment increased in response to the high demand. Producers are increasing existing plant capacities and building or planning new facilities. The future market outlook at this time remains strong.

NOVA SCOTIA POTENTIAL

Titanium-rich sand deposits are known to exist in the beaches along the southeastern coast of Sable Island, Nova Scotia. However, due to the extremely fragile environment and strict provisions placed on any activity on Sable Island, these deposits are of academic interest only. Other titanium-rich sand deposits are known to occur near the mouth of the Shubenacadie River at South Maitland, Hants County, and in sand deposits exposed at low tide in the Cobequid Bay end of the Minas Basin.

During this Various Commodities Project, the heavy mineral sands exposed at low tide in the Shubenacadie River at South Maitland, Hants County, were sampled and analyzed (Figs. 42 and 43). The results of this work are detailed in MacDonald (1989). In summary, concentrations of TiO_2 in the River bed sand reached over 20%. The sand can be concentrated by heavy medium separation, and rutile is the chief TiO_2 ore present. These initial, promising results justify further work at this location and others along the River bed and areas in the Cobequid Bay displaying heavy mineral sands concentrations.

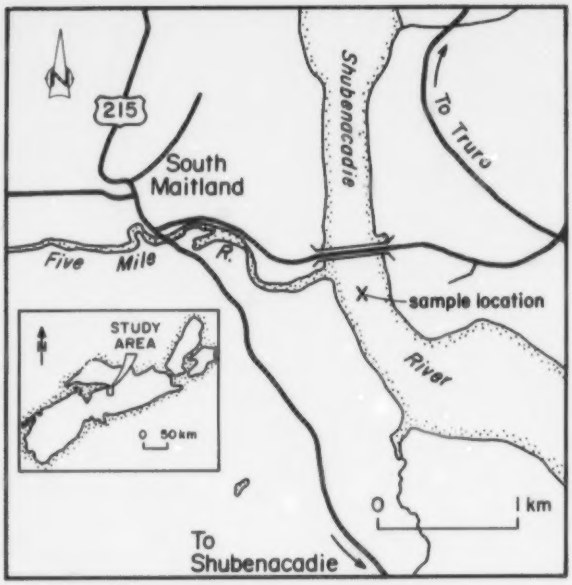

N
215
South Maitland
Shubenacadie
To Truro
Five Mile R.
X
sample location
River
STUDY AREA
0 50km
0
1 km
To Shubenacadie

Figure 42. Location map of the area sampled for heavy mineral sands, Shubenacadie River, South Maitland, Hants County.

Figure 43. Photograph of the black mineral sands in the Shubenacadie River near South Maitland, Hants County.

CHAPTER 14. WOLLASTONITE

The mineral wollastonite is a natural calcium silicate ($CaSiO_3$) usually occurring in cleavable or fibrous masses and sometimes granular and compact. It is usually white, sometimes greyish or brownish, has a hardness of 5 on Mohs scale and a density of 2.9. Wollastonite can be distinguished from other white fibrous silicates, such as sillimanite and tremolite, by its solubility in HCl with the separation of silica. Wollastonite is formed by the metamorphism of siliceous limestones at temperatures around 450°C and higher, and therefore occurs in high grade regionally metamorphosed rocks and near igneous contact zones (Berry and Mason, 1959). Synthetic wollastonite can be manufactured by high temperature sintering of quartz flour and finely ground limestone.

Synthetic wollastonite is crystallized from a homogeneous mixture of raw materials in a 1:1 molecular ratio when heated in a rotary kiln to a temperature below the melting point of wollastonite. A melting phase occurs through reaction with the raw materials aided by the addition of fluxing agents. The crystallization process is carefully regulated using special mineralizing compounds and precise temperature control in the firing zone where the temperature of formation of synthetic wollastonite is around 1450°C.

PRODUCTION AND USES

In 1983 the total world production was estimated at 125 743 t, but this figure does not include production figures from the U.S.S.R., China and smaller operations in Namibia, New Zealand and Japan. A dramatic increase in production over the past 10 years has been encouraged by market demand for various wollastonite products. The wollastonite market is split into two sectors which are differentiated by the degree of acicularity of the material. Low aspect ratio (the ratio between the length of the crystal and its width) wollastonite, commonly in the range of 1:3-1:5, has little potential for reinforcing applications so markets are primarily confined to the ceramics, metallurgical fluxes, and simple filler and coating applications (Power, 1986). High aspect ratio wollastonite that generally ranges from 1:15 to 1:20 is greatly prized as a semifibrous replacement for asbestos and finds high potential growth as a performance filler in the various plastic and resin systems becoming increasingly more common today. Apart from the high aspect ratio, whiteness of the mineral and loss on ignition (LOI) values are very important if the product is going to satisfy criteria required by the various uses. Most wollastonites have good brightness values owing to minimal contamination from iron oxides; these factors are very important in most filler, coating and ceramics applications. LOI values must be <1% in most ceramic and metallurgical applications. Carbon dioxide derived from calcite is emitted during firing of the wollastonite so the more calcite removed during beneficiation techniques, the better the wollastonite in terms of LOI characteristics.

Wollastonite is a comparative newcomer to the mineral filler market and therefore has to show either a competitive price with other alternative materials or prove its worth in terms of performance. In ceramic applications, the largest volume of wollastonite is consumed in wall tile bodies and coating glaze formulations. Fast-firing processes have revolutionized the ceramic body firing times, but the increased speed of production has also brought with it associated physical and chemical problems. Thermal shock, increased mechanical handling and reduced evacuation of the gas phase evolved during firing have all added to the new demands which are being placed on ceramic raw materials employed in this process. In wall tile and glaze applications wollastonite has made considerable inroads into the market as a reinforcing, dimensionally stable, low gas producing additive that has found various degrees of replacement for the more traditional ceramic materials such as limestone, dolomite, talc and feldspar.

CERAMIC APPLICATIONS

The following list of physical and chemical properties of wollastonite illustrates its benefits in ceramic body and glaze formation (Power, 1986):

Acicular Crystal Shape

1. Contributes mechanical reinforcement to the strength of the body and improves pressing quality and green strength to allow new mechanical handling techniques.

2. Imparts high impact strength and dimensional stability to the fired product.

3. Acicular particles also promote good acoustical properties to tile surface.

4. Drying rates are improved in tile and plastic brick bodies owing to the elongated nature of the crystal which acts as a channel for the rapid passage of moisture and thereby reduces moisture expansion.

Thermal Expansion Characteristics

Wollastonite has a low, straight line, thermal expansion coefficient which reduces shrinkage and other dimensional instabilities such as cracking, dunting, grazing and glaze defects.

Loss on ignition

1. Wollastonite generally shows a <1% LOI value which gives minimal gas evolution during firing, especially when compared to that volume of gas generated by the more traditional carbonates and hydrated minerals used in ceramics.

2. As the mineral melts with the minimal of bubbling, this leads to a smooth surface with diminished pin-holing.

Chemical Purity

1. Since iron, titanium and manganese impurities are minimal the mineral retains its high whiteness value on firing.

2. The absence of alkalies also contributes to excellent electrical insulation properties.

3. The mineral has a low sintering temperature around 991-1196°C, similar to that of most natural frits, and fuses readily with alumina and silica, therefore the mineral is most suitable for fast firing techniques.

4. Contributes CaO to alkaline glaze formulations to improve glaze strength, improve surface finish and, in the right quantity, produce matt finish in low-fired glazes.

PAINT APPLICATIONS

Wollastonite as a simple paint system filler has to compete with a variety of cheaper materials and, unless supplies are cheap and readily available, it has limited use. However, in speciality paints such as industrial anticorrosive coatings and textural paint, powder and acicular materials play an important part. The following list outlines the properties effective when wollastonite is used in paint systems (Power, 1986).

Acicular Crystal Shape

1. Needle-like particles act as a good flattening agent and allow paint to settle out after application to produce a dry filler of uniform thickness.

2. Interlocking particles improve toughness and durability of coat with excellent tint retention, scrub and weather resistance.

Colour and Oil Absorption

1. High brightness and whiteness reduces pigment load.

2. Very low oil absorption reduces volume of binder required and contributes to reduced pigment costs.

Chemical Characteristics

In a 10% slurry wollastonite has a pH of 9.9. Although this renders the material unsuitable for some paint systems, it is particularly advantageous in polyvinyl acetate paints (PVA) where it helps to neutralize acidity shift. PVA can decompose into vinyl alcohol and acetic acid, but the presence of wollastonite maintains the alkaline nature of the paint combating corrosion (Power, 1986).

METALLURGICAL APPLICATIONS

Since wollastonite is a natural low temperature fluxing material, significant high volume markets have been developing in steel casting and welding formulations. In recent years, with the establishment of a continuous casting process in the European steel industry, a growing market has developed for wollastonite in fluxing formulations employed in the continuous casting route for steel. When molten steel is poured from the bottom of the refining ladle into the refractory tundish, a flux composite powder is applied to the continuous stream of molten metal. This practice maintains the surface of the flow in a molten state and minimizes surface defects such as scratching that could arise during the pour. Flux formulations containing wollastonite are reported to give better surface finishes to the steel than can be achieved by silica and lime composites. Welding powder formulations also use large tonnages of wollastonite as a flux and slag-forming additive. Wollastonite is favoured because of the improved burn characteristics of the mineral and the inhibition of sparking during the weld owing to its inherent fluxing characteristics (Power, 1986).

ASBESTOS REPLACEMENT

With increasing health legislation over the use of asbestos in various reinforcement applications there exists a growing large volume market for the use of wollastonite as an asbestos substitute. This market, however, is open only to the high aspect ratio materials and then wollastonite is not a perfect substitute because the crystal cannot match the length and flexibility of asbestos fibres. Nevertheless, wollastonite crystals are acicular enough to use as semifibrous reinforcement fillers for boards and panels used in various heat containment applications. Wollastonite is also enjoying increasing use in the replacement of asbestos in certain cement formulations, in ceiling and floor tiling, and in friction applications such as brake linings (Power, 1986).

PERFORMANCE FILLERS IN PLASTICS

There is great potential for the use of the more acicular wollastonite material as a performance filler in the resins and plastics industry. Wollastonite not only reduces the volume of expensive media consumed, but also contributes to physical, chemical and electrical properties of the finished product. In most cases wollastonite offers improved tensile and flexural strength over most other mineral fillers with particularly good moisture repellent properties (Power, 1986).

The following mineralogical properties illustrate the beneficial effects of wollastonite used in thermoplastic (PVC, nylon, polypropylene) and thermosetting resin systems (epoxy, phenolic, polyester).

Acicular Shape of Crystals

1. The crystal structure reinforces the media increasing impact, tensile and flexural strengths.

2. The high hardness of the mineral adds to wear resistance although this may cause abrasion problems in the extrusion casting.

3. High dimensional tolerance reduces shrinkage.

Moisture Pickup and Absorption Properties

1. Very low water absorption in comparison with other mineral fillers.

2. High loadings possibly due to low plasticizer absorption.

3. Also demonstrates low viscosity at high loadings.

4. Compatibility with organic plastic system enhanced by chemical surface coating of grains.

Colour Characteristics

1. High brightness and whiteness together with opaque properties saves pigmentation costs.

2. Smooth surface finish to shapes with high degree of stain resistance due to low water absorption.

Electrical Properties

1. Very good electrical insulation due to low levels of impurities. In polypropylene at 40% loading dielectric constant of 2.74 (Power, 1986).

MARKETS

The two major markets for wollastonite are: (1) as a ground 'powder' material used in ceramics and coating/filler applications, and (2) high aspect ratio material used in asbestos replacement and performance filler applications.

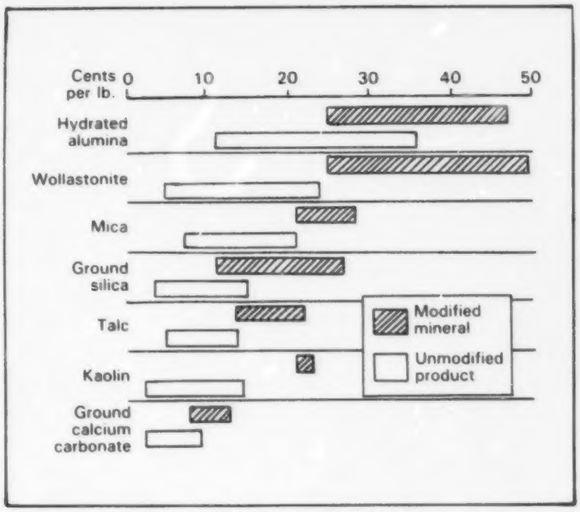
The 'powder' market is not likely to grow due to the plentiful supplies of cheaper and more traditional raw materials for the ceramics industry.

However, the metallurgical markets show considerable potential for growth along with some filler and extender applications where high aspect ratio wollastonite is used in fibreboards and panels as a replacement for asbestos. The lucrative plastics and fillers market where reinforcing characteristics are required has excellent growth prospects for the future where the current United States market of around 8000-10 000 tpa is expected to grow 10-12% per annum. Since many of the applications in thermosetting and thermoplastic media require some degree of chemical surface treatment, this provides considerable added income to the mineral producer. Figure 44 shows the added value effect in cost per pound that is generated by the chemical surface processing of various mineral fillers in the United States.

The trend now for the existing powder wollastonite producers is to invest in sophisticated milling equipment and chemical coating facilities to increase the acicular nature of their products in order to make them more attractive to the plastics and resins market.

FUTURE MARKETS

Future prospects for the wollastonite market appear to be very good with a great deal of healthy investment being concentrated on the long-fibre market. Supplies of ground powder material are totally adequate for future growth and the only area of concern is whether or not producers can satisfy demands for the more acicular material.



Source: C. H. Kline & Co. Chemically Modified minerals – United States 1985

Industrial Minerals, 1986

Figure 44. The added value effect in cost per pound that is generated by the chemical surface processing of the various mineral fillers in the United States.

NOVA SCOTIA POTENTIAL

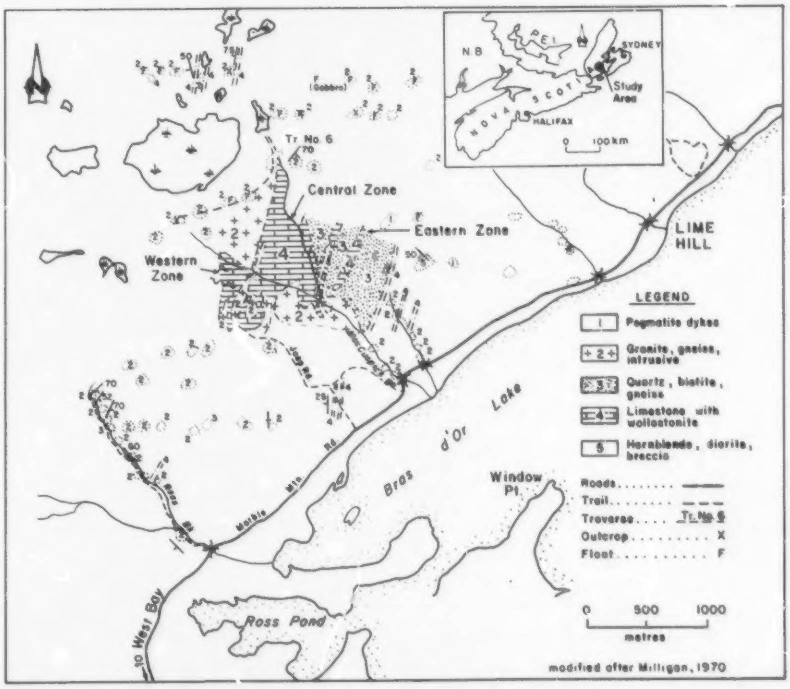
The only known locations within Nova Scotia where siliceous limestones have been subjected to temperatures in the 450°C and higher range occur near areas of regional metamorphism in the George River Group of Cape Breton Island. The only known occurrence of wollastonite to date is located at Lime Hill, Inverness County (Figs. 45 and 46). George River Group carbonates have been metamorphosed by Hadrynian intrusive rocks as well as Devonian granites. The range of metamorphic temperatures, based on the silicate assemblages, is from 250-600°C (Hattie, 1975), well within the range for wollastonite formation.

The fine- to medium-grained, clear to grey calcite marble of the George River Group is interlaced with white to buff, nematoblastic subhedral, acicular aggregates of banded wollastonite up to 1.5 cm in thickness. Wollastonite also occurs in blebs up to 3.0 cm in size. Numerous inclusions of fine, pale green grains of pyroxene (possibly diopside) up to 1 mm in size are disseminated in both the wollastonite and carbonate. Minor quartz is found as interstitial grains in the marble. Very fine grains of pyrite are visible with some of the wollastonite.

Trenching conducted by Bluestack Resources Ltd. in 1986 delineated three wollastonite zones, referred to as the Eastern, Central and Western Zones (Pegg, 1987) (Fig. 45).

The Eastern Zone strikes approximately north-south and extends for over 180 m. The wollastonite varies between 2 and 3 m wide and contains between 25 and 50% wollastonite. The dip appears to be 70°W.

The Central Zone is defined as a multiple zone where several bands of wollastonite are exposed in trenches and intersected by drillholes. The bands dip about 60°W and contain 25-30% wollastonite on average. The bands range from stringers to thicknesses in excess of 2.5 m. The wollastonite content seems to increase to the south. A few deeper drillholes (+150 m) should be drilled on this Central Zone to determine if the wollastonite increases with depth.


N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
Study Area
0 100 km
Tr No. 6
Central Zone
Eastern Zone
Western Zone
LIME HILL
Lake
Bras d'Or
Window Pt.
Ross Pond
to West Bay
Marble Mtn. Rd.
LEGEND
1 Pegmatite dykes
2 Granite, gneiss, intrusive
3 Quartz, biotite, gneiss
4 Limestone with wollastonite
5 Hornblende, diorite, breccia
Roads
Trail
Traverse Tr. No. 6
Outcrop X
Float F
0 500 1000
metres

modified after Milligan, 1970

Figure 45. Location and geology map of wollastonite deposit at Lime Hill, Inverness County.

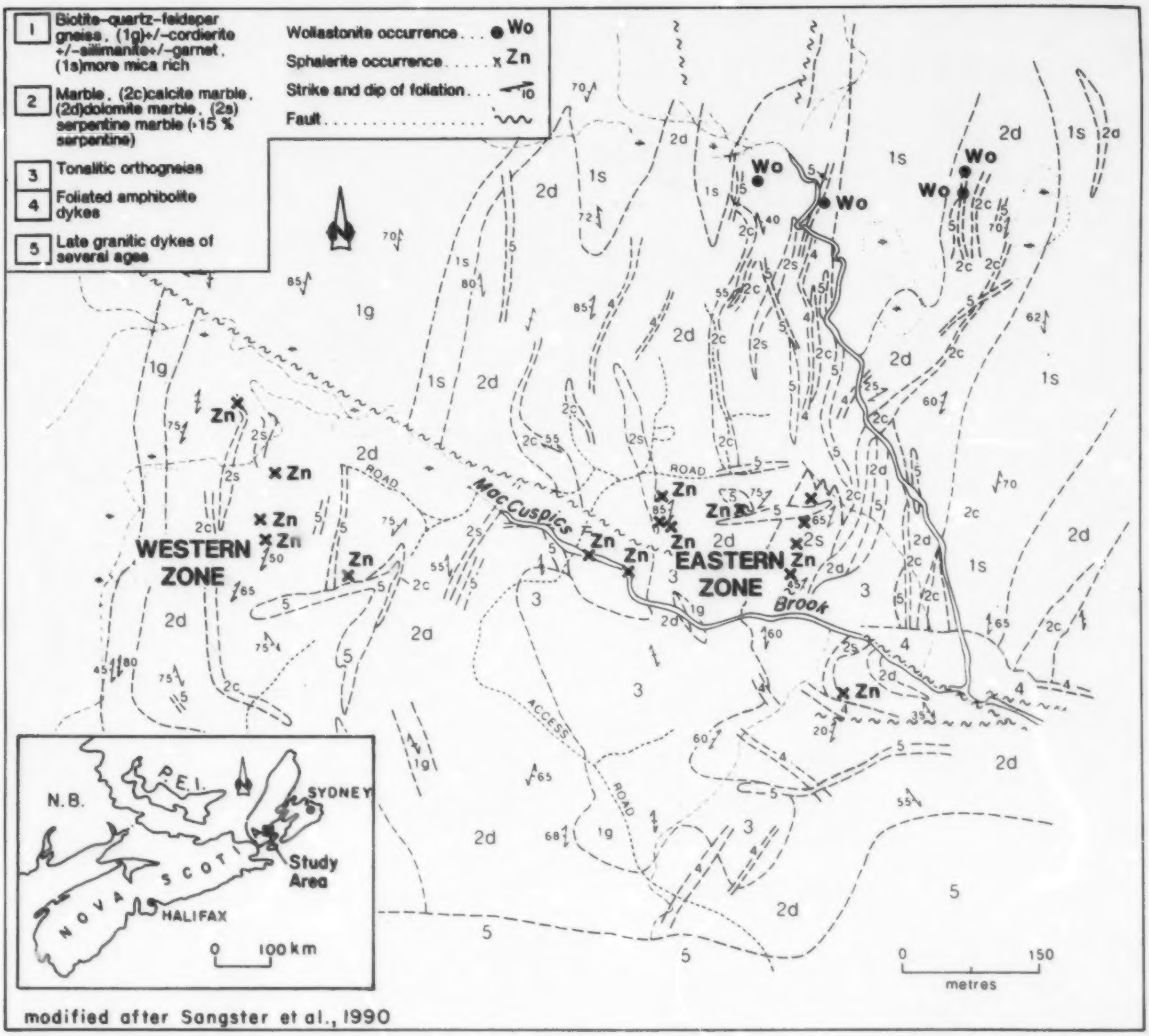

1 Biotite-quartz-feldspar gneiss, (1g)+/-cordierite +/-sillimanite+/-garnet, (1s)more mica rich
2 Marble, (2c)calcite marble, (2d)dolomite marble, (2s) serpentine marble (>15 % serpentine)
3 Tonalitic orthogneiss
4 Foliated amphibolite dykes
5 Late granitic dykes of several ages
Wollastonite occurrence ● Wo
Sphalerite occurrence x Zn
Strike and dip of foliation
Fault
WESTERN ZONE
EASTERN ZONE
MacCuspics Brook
ROAD
ACCESS ROAD
N.B.
P.E.I.
SYDNEY
NOVA SCOTIA
HALIFAX
Study Area
0 100 km
0 150 metres
modified after Sangster et al., 1990

Figure 46. Geology and location of the zinc and wollastonite occurrence, Lime Hill, Inverness County.

The Western Zone appears to be a single horizon reaching a maximum thickness of 2.1 m, although one previous drillhole intersected three bands of wollastonite 1 m, 0.6 m and 0.3 m wide over 12 m. The Western Zone contains an average 25-30% wollastonite. More drilling at depth is necessary on this zone.

During the term of the Various Commodities Project in September 1986, a 4 kg sample of wollastonite ore was collected from the Lime Hill deposit and forwarded to the Mineral Processing Laboratory of the Canada Centre for Mineral and Energy Technology in Ottawa for preliminary assessment testing. This work indicated that the wollastonite could be concentrated by a combination of magnetic separation and flotation. Magnetic separation reduces iron oxide levels to 0.22% Fe_2O_3 in the -600 +300 μm fraction and to 0.28% Fe_2O_3 in the -300 +150 μm fraction. Subsequent reverse flotation of calcite on material ground to -300 μm removed approximately 85% of the calcite, resulting in a concentrated wollastonite product. Aspect ratios of this concentrated product were estimated at between 10:1 and 12:1. Brightness values of this same product are between 68 and 71%.

The results of this preliminary test work indicate that the wollastonite from the Lime Hill deposit can be successfully beneficiated to meet the requirements for use as a filler or extender material in paints and plastics. Further work on a larger representative sample is recommended (Andrews and Kelly, 1987).

Other wollastonite deposits may be possible in other sections of the George River Group carbonates that have been subjected to the same degree of metamorphic temperatures evident at Lime Hill. Temperature is the controlling factor and to date the Lime Hill location is the only known occurrence where the degree of metamorphism was high enough to produce wollastonite.

REFERENCES

Andrews, P. R. A., 1988: Separation of graphite, biotite and micaceous minerals from a Nova Scotia garnet schist; Energy, Mines and Resources Canada, Canada Centre for Mineral and Energy Technology (CANMET), Mineral Sciences Laboratories Division, Report MSL 88-100 (1R).

Andrews, P. R. A. and Collings, R. K., 1990: Barytes in Canada; Industrial Minerals, January 1990, No. 268, p. 46-57.

Andrews, P. R. A. and Kelly, W., 1987: Preliminary assessment of wollastonite from Marble Mountain area, Nova Scotia; Project 30.12.02; Mineral Sciences Laboratories, Canada Centre for Mineral and Energy Technology, Ottawa, April 1987.

AquaGold Resources Ltd., 1990: Report on Glen Morrison limestone deposit; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 90-059.

Austin, G. T., 1987: Garnet, industrial; United States Bureau of Mines, Mineral Commodity Summaries, 1987.

Bell, W. A. and Goranson, E. A., 1938: Bras d'Or Sheet; Geological Survey of Canada, Map 359A, Scale 1:63 360.

Benson, D. G., 1967: Geology of Hopewell map area, Nova Scotia; Geological Survey of Canada, Memoir 343.

Berkovich, S. A., 1958: Report on beneficiation of andalusite bearing rock from Black Point, Guysborough County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/03D 01-G-51(01).

Berry, L. G. and Mason, B., 1959: Mineralogy-Concepts, Descriptions and Determinations; W. H. Freeman and Company, San Francisco, 630 p.

Boehner, R. C., 1980: Preliminary report on the Carboniferous geology of the Antigonish Structural Basin, Antigonish, Nova Scotia; *in* Mineral Resources Division, Report of Activities, 1979; Nova Scotia Department of Mines and Energy, Report 80-1, p. 147-163.

Boehner, R. C., 1987: Carbonate buildups in the early Carboniferous Windsor and Horton Groups, Nova Scotia (a compilation); Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 87-010.

Breen, T. A. E., 1986: Recent developments to produce synthetic mullite and fluorine byproducts from Australian industry topaz; Seventh Industrial Minerals Congress, Monte Carlo 1986, v. I, p. 199-206.

Cadamet Mines Ltd., 1960: Report on stripping, trenching and berylometer survey quartz-beryl vein, Jordan Falls, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 20P/14A 08-P-07(00).

Carbontec Industries Limited, 1986: Graphite, Glendale, Inverness County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 86-051.

Clarke, G., 1986: Titanium minerals - expansions in all the continents; Industrial Minerals, June 1986, p. 47-55.

Cormier, R. F., 1958: A geological report on the andalusite schist occurrence at Black Point, Guysborough County, Nova Scotia, November 1958; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/06A 01-G-01(02).

Crosby, D. G., 1950: Geology, Wolfville, Nova Scotia; Geological Survey of Canada, Memoir 325, Map 1128A, Scale 1:63 360.

Dickie, G. B., 1986: Cretaceous deposits of Nova Scotia; Nova Scotia Department of Mines and Energy, Paper 86-1.

Dunbar, W. R., 1965: The zinc-cadmium deposits in Meat Cove property, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11N/02A 58-J-45(05).

Faribault, E. R., 1920: Investigations in southwestern Nova Scotia; Canada Department of Mines, Geological Survey, Summary Report, 1919, Part F.

Felderhof, G. W., 1978: Barite, celestite and fluorite in Nova Scotia; Nova Scotia Department of Mines and Energy, Bulletin No. 4.

Felderhof, G. W. and MacDonald, R. H., 1984: Report on the MacInnis barite deposit, Scotsville, Cape Breton, Nova Scotia; Scotsville Mineral Resources; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 84-088.

Fletcher, H. and Faribault, E. R., 1887: Report on geological surveys and explorations in the Counties of Guysborough, Antigonish, Pictou, Colchester and Halifax, Nova Scotia, from 1882-1886; *in* Geological Survey of Canada, Annual Report, v. II, p. 19.

Forgeron, S., 1977: The Kaiser Celestite mining operation and mineral potential of the Loch Lomond Basin, Cape Breton, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 328.

Fowler, J. H. and Stea, R. R., 1980: Petrology of Lower Cretaceous silica sands at Brazil Lake, Hants County, Nova Scotia; *in* Mineral Resources Division, Report of Activities, 1980; Nova Scotia Department of Mines and Energy, Report 81-1, p. 47-64.

Geisler, R. A., 1961: Spontaneous polarization and magnetic survey report; Talisman Mines Limited; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 20P/14A 08-P-07(02).

Goranson, E. A., 1931: Silica deposits at Leitch Creek and Skye Mountain, Cape Breton, Nova Scotia; Geological Survey of Canada, Summary Report, 1930, Part D.

Goudge, M. G., 1943: Talc at Brigend Brook; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14D 49-J-07(00).

Goudge, M. G., 1952: Sandstone at Hantsport, Kings County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 21H/01A 44-K-09(00).

Hamer, C. A., 1986: Evaluation of SO_2 sorbent utilization in fluidized beds; Energy, Mines and Resources Canada, Canada Centre for Mineral and Energy Technology, Report 86-9E.

Harris, T. S., Gauntt, G. E., Bausback, D. B. and Mocarski, S. J., 1987: Opportunities in Specialty Silicas; Kline and Company, Inc., Fairfield, New Jersey.

Hattie, D., 1975: Geological review, with emphasis on structure of the Silvermaque option of Brascan Resources Ltd., Lime Hill, Cape Breton, N.S., May 1975; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14A 58-J-33(08).

Hill, J. R., 1989: Geology and geochemistry of Precambrian carbonate rocks, Cape Breton Island, Nova Scotia; Geological Survey of Canada, Open File 1597, 557.16H646.

Hunter, D., 1989: Stirling property, Cape Breton, Nova Scotia; Earthunt Resources Inc. for Wilco Mining Company Limited; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 89-123.

Industrial Garnet Extractors, 1983: Information circular on garnets; Industrial Garnet Extractors, A Division of World Minerals Inc.

Industrial Minerals, 1985: Sillimanite minerals - Europe places demands on andalusite; Industrial Minerals, January 1985.

Industrial Minerals, 1986: Wollastonite performance filler potential; Industrial Minerals, January 1986.

Jones, B., 1963: Preliminary report - silica project, Yarmouth County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 027.

Kelley, D. G., 1967: Baddeck and Whycocomagh map areas; Geological Survey of Canada, Memoir 351.

Kramer, D. A., 1986a: Beryllium; *in* Metals and Minerals, Volume 1; United States Bureau of Mines, Minerals Yearbook, 1986.

Kramer, D. A., 1986b: Magnesium compounds; *in* Metals and Minerals, Volume 1; United States Bureau of Mines, Minerals Yearbook, 1986.

Kramer, D. A., 1987: Magnesium metal; United States Bureau of Mines, Mineral Commodity Summaries, 1987.

Luke, P., 1990: Filler and extender minerals in Nova Scotia; Nova Scotia Department of Mines and Energy, Economic Geology Series 90-2.

Luke, P. and MacDonald, R. H., 1988: Limestone and dolomite in Nova Scotia; Nova Scotia Department of Mines and Energy, Information Circular 13.

Lynd, L. E. and Hough, R. A., 1986: Titanium; *in* Metals and Minerals, Volume 1; United States Bureau of Mines, Minerals Yearbook, 1986.

MacDonald, R. H., 1989: Shubenacadie River heavy mineral sands; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 89-020.

MacDonald, R. H., 1990a: 1988 Glencoe drilling program, Inverness County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 90-020.

MacDonald, R. H., 1990b: Summary of the major limestone/dolomite deposits of Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 90-019.

MacDonald, R. H., 1990c: Glencoe limestone deposit, Inverness County, 1988 drilling program (11F/14C); Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Map 90-002, Scale 1:6000.

MacDonald, R. H., 1990d: Investigation of the Chegoggin Point, Lake George, Yarmouth County, silica and garnet deposit; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 90-009.

MacDonald, R. H., 1991: Silica in Nova Scotia; Nova Scotia Department of Natural Resources, Information Circular 14, second edition.

MacNeil, D. J., 1972: Report on diamond drilling limestone and dolomite deposits, Kewstoke, Inverness County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14D 28-J-30(03).

MacNeil, D. J., 1974: Preliminary report on diamond drilling, Glencoe, Inverness County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14C 28-J-21(03).

MacNeil, D. J., 1977: The Glencoe limestone and dolomite survey; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 329.

MacNeil, D. J., 1978: Geology and diamond drilling report on dolomite deposit at Kellys Cove, Victoria County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11K/08B 16-Q-40(02).

McMichael B., 1990: Alumino-silicate minerals, refractories steel the show; *in* Industrial Minerals, October 1990, No. 277, p. 27-43.

Messervey, J. P., 1926: Talc, soapstone in Nova Scotia; Nova Scotia Department of Mines, Pamphlet No. 27.

Messervey, J. P., 1931: Memos on graphite, Glendale, Inverness County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14B 23-J-23(00).

Messervey, J. P., 1933: Graphite in Nova Scotia; Nova Scotia Department of Mines, Pamphlet No. 11.

Messervey, J. P., 1965: Report on the base metal property of Keltic Mining Corp. Ltd., Stirling, Richmond County, N.S.; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/09C 58-O-25(08).

Milligan, G. C., 1970: Geology of the George River series, Cape Breton; Nova Scotia Department of Mines, Memoir 7.

Murray, D. A., 1975: Limestones and dolomites of Nova Scotia, Cape Breton Island; Nova Scotia Department of Mines, Bulletin No. 2, Part II.

Nova Scotia Department of Mines, 1963: Report on diamond-drill hole #1 at Campbell Brook, Inverness County; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14A 28-J-08(00).

Nova Scotia Research Foundation, 1963: Limestone deposit Southside Antigonish Harbour, Report 13-63; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 413.

Nova Scotia Research Foundation, 1969: Notes on Geophysical Surveys in Goshen area and recommendations for future explorations; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 21H/01D 07-I-15(04).

Oldale, H. R., 1959: Beryllium explorations in southwestern Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 072.

Ober, G. A., 1988: Strontium, uses, supply and technology; United States Bureau of Mines, Information Circular 9213.

Pegg, C. W., 1987: Report on Lime Hill wollastonite property; Bluestack Resources Limited; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 87-272.

Power, T., 1986: Wollastonite, performance filler potential; Industrial Minerals, January 1986.

Prud'Homme, M., 1985: Graphite; *in* Canadian Minerals Year Book, 1985, Review and Outlook; Energy, Mines and Resources Canada, Mineral Report 34, p. 29.1-29.13.

Rozovsky, H., 1958: Aluminum, Dorts Cove, Guysborough County, Nova Scotia; Canadian Alumina Corporation diamond drilling report; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/06B 01-G-09(02).

Sabina, A. P., 1965: Rocks and minerals for the collector: northeastern Nova Scotia, Cape Breton and Prince Edward Island; Geological Survey of Canada, Paper 65-10.

Sangster, A. L., Justino, M. F. and Thorpe, R. I., 1990: Metallogeny of the Proterozoic marble-hosted zinc occurrences at Lime Hill and Meat Cove, Cape Breton Island, Nova Scotia; *in* Mineral Deposit Studies in Nova Scotia, Volume 1, ed. A. L. Sangster; Geological Survey of Canada, Paper 90-8, p. 31-66.

Schiller, E., 1961: Geology, Guysborough, Nova Scotia; Geological Survey of Canada, Map 27-1961, Scale 1:63 360.

Shaw, W. G., 1975: Dolomite, Churchview, Inverness County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14D 16-J-14(03).

Shaw, W. S., 1982: Dolomite deposit, Churchview area, Inverness County, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11F/14D 16-J-14(04).

Shea, F. S. and Murray, D. A., 1967: Limestones and dolomites of Nova Scotia, Cape Breton Island; Nova Scotia Department of Mines, Bulletin No. 2, Part I.

Spence, H. S., 1943: Report on inspection of talc occurrences at Frasers Mill, near Whycocomagh, Cape Breton, Nova Scotia; Bureau of Mines, Ottawa, November 1943.

Taylor, F. C., 1967: Geology of Shelburne area, Nova Scotia; Geological Survey of Canada, Memoir 349.

Taylor, H. A., 1986: Graphite; *in* Metals and Minerals, Volume 1; United States Bureau of Mines, Minerals Yearbook, 1986.

Toon, S., 1986: Abrasive minerals - hard work in soft markets; Industrial Minerals, December 1986, p. 53-73.

Tull, J. F., Allison, D. T. and Groszos, M. S., 1989: Geologic interpretations of andalusite deposits, Meguma Terrane, Nova Scotia, Canada; Nova Scotia Department of Natural Resources, Assessment Report 89-092.

Walsh, B., 1971: Report on the Brazil Lake spodumene occurrence; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 20P/13C 29-R-02(01).

Webb, T. C., 1986: Limestone in New Brunswick, past, present and future; New Brunswick Department of Natural Resources and Energy.

Weeks, L. J., 1954: Southeast Cape Breton Island; Geological Survey of Canada, Memoir 277.

Wright, J. D., 1964: Silica - its uses, specifications, and description of deposits in Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Open File Report 087.

Zurowski, M., 1971: Report on the exploration and development activities conducted on the holdings of International Mogul Mines Ltd. and New Mount Costigan Mines Ltd. for 1971 in the Ainslie Lake area, Inverness County, Nova Scotia, Parts 1 and 2; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Assessment Report 11K/03A 06-J-31(12).

Zurowski, M., 1972: Barite/fluorite deposits of Lake Ainslie - an appraisal from an economic viewpoint; Trans Canada Institute of Mining and Metallurgy, v. 75, p. 318-321.

APPENDIX 1.

SEPARATION OF GRAPHITE, BIOTITE AND MICACEOUS MINERALS FROM A NOVA SCOTIA GARNET SCHIST

(ANDREWS 1988)

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

SEPARATION OF GRAPHITE, BIOTITE AND MICACEOUS MINERALS FROM A NOVA SCOTIA GARNET SCHIST

P.R.A. Andrews
Mineral Processing Laboratory

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MINERAL SCIENCES LABORATORIES
DIVISION REPORT MSL 88-100 (IR)

SEPARATION OF GRAPHITE, BIOTITE AND MICACEOUS MINERALS FROM A NOVA SCOTIA GARNET SCHIST

by

P.R.A. Andrews*

ABSTRACT

A preliminary evaluation was conducted to concentrate garnet from a graphitic, micaceous garnet schist from Chegoggin Point, Nova Scotia. Graphite and illite were successfully removed by a combination of scrubbing and washing. The best scrubbing time was determined as 20 min; scrubbing times in excess of 20 min resulted in abraded garnet surfaces.

Gravity concentration employing laboratory shaking tables concentrated garnet in the -840 +420 µm fraction to 70-75% garnet; in the -420 +150 µm fraction to 80-85% garnet and in the -150 µm fraction to 95% garnet. Although garnet was effectively liberated in the -2.4 mm +840 µm fraction, concentration by tabling was not possible due to a combined effect of similarity in shape and specific gravity between garnet and chlorite, which was more critical at coarser sizes than finer sizes.

Garnet in the -840 +420 µm fraction was further concentrated by reverse flotation of chlorite to 85% garnet. Chlorite was floated at pH 8.0, after prior grinding and desliming at 45 µm to remove illite, using a tertiary amine collector Ethomeen T 25. A chlorite product analyzing 70% chlorite was obtained with 384 g/t of collector. At this pH garnet was unresponsive to Ethomeen T 25.

Keywords: garnet, graphite, chlorite, gravity concentration, flotation

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SÉPARATION DU GRAPHITE, DE LA BIOTITE ET DES MINÉRAUX MICACÉS D'UN SCHISTE À GRENAT DE LA NOUVELLE-ÉCOSSE

par

P.R.A. Andrews*

RÉSUMÉ

Une première évaluation a été effectuée pour concentrer le grenat provenant d'un schiste à grenat graphiteux et micacé de Chegoggin Point en Nouvelle-Écosse. Le graphite et l'illite ont été séparés avec succès par épuration et lavage combinés. Le meilleur temps pour l'épuration a été déterminé à 20 minutes; des temps d'épuration plus longs ont donné des surfaces abrasées de grenat.

La concentration par gravité au moyen de tables à secousses de laboratoire a donné dans la fraction -840 +420 µm, entre 70 % et 75 % de grenat; dans la fraction -420 +150 µm de 81 % à 85 %, et dans la fraction -150µm, 95 %. Bien que le grenat soit libéré dans la fraction -2,4 mm +840 µm, sa concentration par tables à secousses n'a pas été possible du fait que le grenat et la chlorite étaient de forme et de densité semblables, similitude qui était plus prononcée pour les grains grossiers que pour les grains fins.

On a poussé à 85 % la concentration du grenat présent dans la fraction -840 +420 µm par flottation inverse de la chlorite. La chlorite était séparée par flotation à pH 8, après broyage et déschlammage à 45 µm pour éliminer l'illite, en présence du collecteur Ethomeen T 25, qui est une amine tertiaire. On a obtenu un produit chloriteux renfermant 70 % de chlorite avec 384 g de collecteur par tonne. À ce pH, le grenat était réfractaire à l'Ethomeen T 25.

Mots clés : grenat, graphite, chlorite, concentration par gravité, flottation

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INTRODUCTION

In October 1987, R. MacDonald of the Nova Scotia Department of Mines, Stellerton, Nova Scotia, discussed with the Industrial Minerals Section the possibility of concentrating garnet from a deposit occurring at Chegoggin Point, Nova Scotia. Subsequently, a 20 kg sample of garnet schist was received in November 1987.

The presence of garnetiferous schist at Chegoggin Point has been known for many years. The deposit was originally reported by Faribault (1919) and preliminary concentration tests conducted by Flynn (1923) and again by Cameron (1952). Results of testwork indicated that concentration of garnet using magnetic and gravity concentration techniques was only partially successful. Magnetic separation produced 60% garnet concentrates at sizes below 600 µm; chlorite could not be effectively separated. Similarly, with tabling at sizes below 800 µm no definite division between concentrate, middling and tailing was possible due to the presence of chlorite.

Before 1987 very little commercial interest was shown in the garnet deposits, although the white quartzite, which overlies the garnet schist, was mined by Dominion Steel and Coal Corporation.

GEOLOGY

The strata at Chegoggin Point cuts the coast line obliquely, the regional strike being N35° to 40°E, magnetic, and the dip approximately 80°E. As exposed along the beach, the rocks are highly metamorphosed to various crystalline schists and slates of varying composition, being micaceous, hornblendic, pyritic or garnetiferous. Exposures of relatively pure hornblende were noted and in places the weaker mica schists curve around the hornblende masses. Several quartz veins were noted, which cut the strata at a very low angle. The quartz veins, as exposed, averaged 200 to 250 mm wide, but were discontinuous over short distances.

Various beds were identified; some appeared to be predominately mica schists containing a few small garnets, while other schists were rich in garnets, the estimated bed thickness being approximately 3 m.

SAMPLE DESCRIPTION

Approximately 20 kg of a garnetiferous graphite micaceous schist, consisting of several large 200 mm ore specimens were received at the Industrial Minerals Laboratory in November 1987. The garnet crystals were subhedral to euhedral in shape ranging in size from 1 mm to 6 mm; the majority being 3 to 4 mm in size, and the entire mineral surfaces were coated with a film of graphite. Other impurities included minor amounts of quartz, and some iron staining on the micaceous minerals which indicated the presence of non-sulphides. The garnet content was estimated to be 50-60% and garnet grains appeared to have a hackly-chisel fracture when crushed with no visible magnetite inclusions.

PROCESSING

Size Reduction

The 20 kg sample was crushed to pass 6 mm and examined visually to assess coarse liberation of garnet. Since there was virtually no coarse liberation, size reduction was continued to 2.4 mm.

Head Sample

A representative 200 g head sample was screened from 2.4 mm to 150 µm and each fraction examined by binocular microscopy to determine mineral content and degree of liberation with decreasing size; results are reported in Table 1.

Secondary Crushing and Sizing

The remainder of the 20 kg sample was further size reduced by roll crushing to pass 840 µm, the garnet liberation size, and sized at -840 +420 µm, -420 +150 µm and -150 µm.

Scrubbing

Visual examination of the three size fractions suggested that processing of the intermediate -420 +150 µm fraction would benefit from a preliminary attrition scrubbing to remove graphitic and chloritic slime. A

1 kg portion was scrubbed at 85% solids in a laboratory Wemco attrition scrubber for 30 min and wet screened at 150 μm to remove slime-forming minerals. Visual assessment indicated that the garnet surfaces were free of graphite, but the surfaces had become abraded and rounded by attrition.

Three scrubbing tests were conducted for 10 min, 20 min and 30 min scrubbing times to determine the optimum time which would least abrade garnet surfaces, but still be sufficient to liberate graphite and micaceous mineral slimes. Visual assessment indicated that scrubbing time should not exceed 20 min.

Gravity Concentration

Portions of -2.4 mm +840 μm, -840 +420 μm and -420 +150 μm size fractions were passed over a Wilfley shaking table, and the -150 μm fraction over a Wilfley slime table to ascertain how efficiently garnet would be concentrated by gravity concentration techniques. The -420 +150 μm fraction was the only size fraction that was scrubbed prior to tabling to remove graphite and micaceous mineral slimes. Visual observations of all products from tabling are reported in Table 2. Product balances for the -420 +150 μm and -150 μm fraction tests, based on X-ray diffraction data, are reported in Table 3.

Graphite Flotation

It was observed during scrubbing tests that liberated graphite formed a film on the surface of the attrition-product mix. A 1 kg sample of -420 +150 μm material was scrubbed for 20 min with NaOH, fuel oil and MIBC (methyl iso-butyl carbinol) frother. After scrubbing a standard graphite float was conducted in a laboratory Denver flotation cell and the graphite concentrate analyzed for carbon.

Micaceous Minerals Flotation

The products from the -840 +420 μm gravity concentration test were re-combined and crushed to pass 600 μm, and riffled into 500 g lots for flotation. Each 500 g lot was wet-ground at 50% solids in a porcelain jar mill with burundum grinding media, and transferred to the laboratory Denver flotation cell. Flotation of micaceous minerals from garnet was conducted using two flotation procedures. A primary amine, Armac T, tallow amine acetate was employed at pH 8, and a tertiary amine, Ethomeen T 25, polyoxyethylene tallow amine between pH 7.0 and 9.4. Selected micaceous products and garnet concentrates were examined by binocular microscope and analyzed by X-ray diffraction. Flotation testwork product balances are reported in Table 4, and flotation parameter and reagent concentration data in Table 5.

Analysis

X-ray diffraction analysis is a semi-quantitative technique and accuracy is interpreted as ±10%, although analyses are reported to the nearest 5%.

RESULTS

Although garnet was approximately 90% liberated from chlorite and graphite in the -2.4 mm +840 μm fraction, a separation, using a laboratory shaking table was not possible due to a combined effect of similarity in shape and specific gravity between garnet and chlorite, which was more critical at coarser sizes than finer sizes. Better separation between garnet and chlorite might be obtained by jigging at this coarse size. Concentration of garnet improved with decreasing size fractions from 70-75% garnet at -840 +420 μm; 80 to 85% garnet at -420 +150 μm and 95% garnet at -150 μm. Although the principal gangue minerals were chlorite and graphite, the presence of illite in the -150 μm was a major contaminant mineral in this fraction.

The results of a preliminary graphite flotation test indicated that a rougher concentrate analyzing 7.5% C could be obtained. Cleaning would undoubtedly increase the carbon content but this was not attempted.

Further concentration of garnet in the -840 +420 μm fraction was attempted by flotation. Flotation of garnet using the primary amine collector, Armac T, (Test 1) did not significantly increase the grade of garnet concentrate. Better results were obtained with reverse flotation of chlorite using the tertiary amine collector Ethomeen T 25. In Test 2, after grinding, a desliming stage at 25 μm removed 30.6% of the illite for a loss of only 6.9% of the garnet. Flotation removed 32.2% of the chlorite, so that while 92.1% of the garnet was recovered, the concentrate (rougher tails product) was only upgraded to 80%. In Test 3, the desliming size was increased to 45 µm at which size 24.4% of the illite and 42.0% of the chlorite were removed. The increase in the rejection of chlorite indicates that chlorite particles are coarser than 25 µm. Flotation rejected a further 36.6% of the chlorite so that the garnet concentrate (rougher tails product) was increased to 85% garnet. The recovery at 85.3% was less than in Test 1 due to the greater loss of garnet, 14.1%, in the slime fraction. In Test 4, the desliming size was further increased to 70 µm to ascertain whether greater weight rejection of slime material would improve flotation. At 70 µm the rejection of chlorite increased to 59.9%, the illite rejection was approximately the same as in Tests 1 and 2, at 31.9%; garnet loss increased to 17.0%. Flotation rejected a further 25.1% chlorite but the grade of garnet concentrate was not increased above that obtained in Test 3. In Test 5, the grind time was increased in an attempt to ascertain whether a finer grind would liberate more gangue and improve the selectivity of the garnet concentrate. The results show that while a 90% garnet concentrate (rougher tails product) was obtained, the recovery was reduced to 51%. The principal reason for the reduced recovery being the loss of 37.1% of the garnet in the initial desliming stage.

PHYSICO-CHEMICAL CONSIDERATIONS

Surface Charge

The zero point of charge of garnet has been variously determined between 4.4 (Cases, 1970) and 5.8 (Fuerstenau & Fuerstenau, 1983). Garnet belongs to the orthosilicate crystal group and is characterized by non-sharing of oxygen atoms within the SiO_4 structural unit. This structure on fracturing produces a polar surface and exposed Fe^{3+} and Al^{3+} become hydrolized; as such H^+ and OH^- would be expected to be potential determining ions. Indirect evidence that Fe^{3+} and Al^{3+} can affect the z.p.c. was demonstrated by comparing the flotation behaviour of acid-treated garnet with untreated garnet; acid-treatment reduces the flotation response.

The zero point of charge of chlorite has not been determined; the z.p.c. of a similar sheet silicate mineral, biotite, is 0.4 (Fuerstenau & Fuerstenau, 1983). The z.p.c. of chlorite would be expected to be similar, but variability is suspected due to the presence of Fe^{3+}, Al^{3+} and Mg^{2+} as replacement cations in the mineral lattice. Abramov, 1965 has made an extensive study of the surface properties of chlorite and concluded that the surface consists both of partly hydrophobic and hydrated portions. The existence of weakly acidic Si-OH and amphoteric Al-OH layers are thought to influence floatability.

Adsorption Mechanisms

Garnet responds to anionic and cationic flotation. When employing oleic acid, evidence of chemisorption and electrostatic adsorption from infra-red spectroscopy studies was demonstrated by Pol'kin, Kolmogorova and Solo'ev, 1971. The garnet spectra showed bands for Fe and Al oleates in addition to bands characteristic of the undissociated acid. Adsorption of dodecylamine by electrokinetic potential measurements indicated chemical adsorption of amine ions on the garnet surface and physical adsorption of undissociated amine molecules in the diffused portion of the electrical double layer (Naifonov, 1967).

Chlorite responds to anionic and cationic flotation; in fact chlorite displays the largest flotation area of the sheet-silicate minerals. Manser, 1975 found that there was no lower pH limit with either oleic acid or dodecylamine and only the anionic collector displayed an upper pH limit of between pH 8 and 10. There is an absence of fundamental adsorption data for chlorite but such positive response to flotation would imply both chemisorption and electrostatic adsorption.

Garnet-Chlorite Separation

The flotation of chlorite at pH 8 using the tertiary amine collector Ethomeen T 25 is most likely to occur in an area of negative surface potential and would indicate electrostatic adsorption. Proof of electrostatic adsorption would be demonstrated by non-flotation at pH values below the z.p.c. when chlorite would be positively charged. At pH 8 garnet is unresponsive to Ethomeen T 25.

CONCLUSIONS

Scrubbing effectively removed graphite from garnet surfaces; washing and desliming removed both graphite and illite. Gravity concentration using laboratory shaking tables concentrated garnet in the -840 +420 µm fraction from 70-75% garnet; in the -420 +150 µm fraction from 80-85% garnet and in the -150 µm fraction to 95% garnet. Although garnet was effectively liberated in the -2.4 mm +840 µm fraction, concentration by laboratory shaking table was not possible due to a combined effect of similarity in shape and specific gravity between garnet and chlorite, which was more critical at coarser sizes than finer sizes. By grinding the -840 +420 µm fraction, flotation further improved the garnet concentration from 70 to 75% garnet, to 85% garnet. Further increase in grade to 90% garnet was possible but only with a reduced recovery.

RECOMMENDATIONS

Further testwork at the laboratory and possibly pilot-plant level should be conducted with a larger sample to establish a more selective beneficiation procedure. If garnet from Chegoggin Point can be beneficiated to the extent required for its various uses then the following recommendations would apply:

1. A market study should be conducted to establish size and variety of markets, competition from substitute materials and product evaluation with specifications for the requirements pertaining to the type and acceptable level of deleterious material.

2. Cost benefit analysis should be conducted to establish cut-off grade.

3. Additional diamond drilling should be undertaken to determine ore grade and extent of the deposit.

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REFERENCES

Abramov, A.A. (1965) Flotation of sericite and chlorite in the presence of cationic collectors, Obogashch Rud 8(5), pp. 3-9, (Chem. Abstr. 62 8716d).

Cameron, E.L. (1952) Garnets at Chegoggin Point, Yarmouth, Nova Scotia, Technical University of Nova Scotia, Halifax, Nova Scotia.

Cases, J.M. (1970) On the normal interaction between adsorbed species and adsorbing surface, Trans AIME Vol 247 p. 123.

Faribault, E.R. (1919) Geology of the garnet schist deposits at Chegoggin Point, Nova Scotia, Summary Report Part F, Geological Survey of Canada.

Flynn, A.E. (1923) Report on the separation of garnets from garnet-bearing rock from Chegoggin Point, Yarmouth, Nova Scotia, Technical University of Nova Scotia, Halifax, Nova Scotia.

Fuerstenau, D.W. & Fuerstenau, M.C. (1983) The flotation of oxide and silicate minerals, Ch 7, Principles of Flotation, Monograph No. 3, S. African Inst. Min. Metall.

Manser, R.M. (1973) Handbook of Silicate Flotation, Warren Spring Laboratory, Stevenage, Herts., England p. 129.

Naifonov, T.B. (1967) Reaction of cationic collectors with tantalite and some associated minerals, Obogashch, Polez, Iskop. Kol'sk Polvostrova, Akad. Nauk. SSSR, Kol'sk Filial. pp. 41-45 (Chem. Abstr. 67 46099a).

Pol'kin, S.I., Kolmogorova, V.I. & Solo'ev, L.S. (1971) Reaction of oleic acid with some minerals, Spektrosk., Tr. Sib. Soveshch., 4th pp. 118-121 (Chem. Abstr. 74 17510s).

Table 1. Mineralogy of sized fractions

Size fraction µm	Description
+9.5 mm	Aggregates of euhedral garnet crystals are locked in a chlorite-biotite-graphitic schist; minor quartz present, minor limonitic staining. Graphite coats the unfractured garnet surfaces.
-9.5 +6.7 mm	Similar to +9.5 mm fraction.
-6.7 +3.4 mm	50 to 60% of this fraction euhedral garnet with the crystal surfaces coated with graphite; liberation of garnet from matrix complete.
-3.4 +2.4 mm	Similar to -6.7 +3.4 mm fraction; combined -6.7 +2.4 mm fraction accounts for most of the garnet.
-2.4 +1.2 mm	Garnet crystals are beginning to be fractured; graphite surface coating is still present.
-1.2 mm +600 µm	Similar to -2.4 + 1.2 mm fraction.
-600 +300 µm	Garnet grains are free of graphite coating; only 15 to 20% of this fraction is garnet.
-300 +150 µm	Garnet grains are clean but only 20 to 30% of the fraction is garnet; biotite/chlorite well delaminated.
-150 µm	Garnet accounts for 15% and quartz 10% of this fraction; majority is biotite/chlorite.

Table 2. Shaking table gravity concentration testwork

Size fraction	Remarks
-2.4 mm +840 µm	Although garnet was approximately 90% liberated from chlorite and graphite, some garnet faces were still coated by graphite. No visible concentration was observed.
-840 +420 µm	Concentration was estimated at 70 to 75% garnet. The garnet faces were clean and angular displaying the chisel fracture. Garnet content in the tails was estimated to be 5%.
-420 +150 µm	The concentrate and middlings fractions were estimated to contain 80 to 85% garnet. The garnet faces were extremely clean with good angularity. Minor contaminant minerals included quartz with magnetite inclusions, and chlorite. The tails were mainly chlorite with minor garnet and illite. This fraction was the only fraction that was scrubbed to remove illite prior to tabling.
-150 µm	Concentration was estimated at 95% garnet.

Table 3. Product balances for selected gravity concentration testwork

Products	Weight %	Analysis %				Distribution %			
		Garnet	Quartz	Chlorite	Illite	Garnet	Quartz	Chlorite	Illite
-420 +150 µm									
Concentrate	47.3	78	14	8	-	64.9	80.2	13.0	-
Middling	20.5	85	8	7	-	30.6	19.8	4.9	-
Concn + Midd.	67.8	80	12	8	-	95.5	100.0	17.9	-
Tailings	32.2	8	-	74	19	4.5	-	82.1	100.0
Calculated head	100.0	57	8	29	6	100.0	100.0	100.0	100.0
-150 µm									
Concentrate	36.3	96	-	4	-	63.9	-	6.3	-
Middling	27.4	56	-	27	17	28.1	-	31.9	45.9
Tailings 1	36.3	12	-	40	31	8.0	-	61.8	54.1
Calculated head	100.0	55	-	23	22	100.0	-	100.0	100.0

Table 4. Flotation testwork product balances

Test No.	Products	Weight %	Analysis %			Distribution %		
			Garnet	Chlorite	Illite	Garnet	Chlorite	Illite
1	Rougher float	84.0	70	15	15	-	-	-
	Rougher tails	16.0	-	-	-	-	-	-
	Calculated head	100.0	-	-	-	-	-	-
2	Slime	8.4	60	35	5	6.9	17.5	30.6
	Rougher float	7.2	10	75	15	1.0	32.2	7.9
	Rougher tails	84.4	80	10	10	92.1	50.3	61.5
	Calculated head	100.0	73	17	14	100.0	100.0	100.0
3	Slime	20.0	50	35	15	14.1	42.0	24.4
	Rougher float	8.7	5	70	25	0.6	36.6	17.7
	Rougher tails	71.3	85	5	10	85.3	21.4	57.9
	Calculated head	100.0	71	17	12	100.0	100.0	100.0
4	Slime	28.0	40	45	15	17.0	59.9	31.9
	Rougher float	8.8	10	60	30	1.6	25.1	20.1
	Rougher tails	63.2	85	5	10	81.4	15.0	48.0
	Calculated head	100.0	66	21	13	100.0	100.0	100.0
5	Slime	43.5	60	25	15	37.1	63.8	64.0
	Rougher float	16.7	50	25	25	11.9	24.5	16.5
	Rougher tails	39.8	90	5	5	51.0	11.7	19.5
	Calculated head	100.0	70	17	10	100.0	100.0	100.0

Table 5. Flotation parameter and reagent concentration data

Test No.	Flotation stage	No. of stages	Grind time min	Deslime size μm	Float time min	pH	Collectors		Frother
							Arm. T g/t	Eth T 25 g/t	M.I.B.C. g/t
1	Rougher	3	10	-	8.5	8.2	782.7	-	75.1
2	Rougher	2	10	-25	5	9.5	-	557.4	80.3
3	Rougher	2	10	-45	5.5	8.0	-	384.3	46.1
4	Rougher	4	10	-70	11.5	8.2	-	862.6	135.9
5	Rougher	4	20	-70	11.5	8.3	-	1453.0	171.7

APPENDIX 2.

RESULTS OF ANALYSES ON SAMPLES SUBMITTED FROM GLENCOE

(MINERALS ENGINEERING CENTRE, TECHNICAL UNIVERSITY OF NOVA SCOTIA

AND LAFARGE CANADA INC.)

APPENDIX 2.
RESULTS OF ANALYSES ON SAMPLES SUBMITTED FROM GLENCOE (MINERALS ENGINEERING CENTRE, TECHNICAL UNIVERSITY OF NOVA SCOTIA (TUNS) AND LAFARGE CANADA INC.)

Sample Number	Depth		CaO %		MgO %	
	(m)	(ft)	(TUNS)	(Lafarge)	(TUNS)	(Lafarge)
I-3-1	45.8-48.8	(150-160)	53.48		0.23	
I-3-2	61.0-64.1	(200-210)	52.94		0.22	
I-3-3	76.3-79.3	(250-260)	52.46		0.20	
I-3-4	91.5-94.6	(300-310)	53.98		0.16	
I-3-5	106.8-109.8	(350-360)	53.53		0.19	
I-3-6	122.0-125.1	(400-410)	53.67		0.23	
I-3-7	137.3-140.3	(450-460)	53.10		0.19	
I-3-8	152.5-155.6	(500-510)	53.16		0.25	
I-3-1A	45.8-48.8	(150-160)	53.13	53.83	0.23	0.46
I-3-2A	61.0-64.1	(200-210)	52.82	53.29	0.21	0.45
I-3-3A	76.3-79.3	(250-260)	52.81	53.49	0.17	0.48
I-3-4A	91.5-94.6	(300-310)	54.15	54.58	0.17	0.38
I-3-5A	106.8-109.8	(350-360)	53.25	53.43	0.22	0.48
I-3-6A	122.0-125.1	(400-410)	53.00		0.30	
I-3-7A	137.3-140.3	(450-460)	53.59		0.19	
I-3-8A	152.5-155.6	(500-510)	53.18		0.20	
I-3-9A	167.8-170.8	(550-560)	52.69		0.24	
I-3-10A	183.0-186.1	(600-610)	53.53		0.17	
I-3-11A	198.3-201.3	(650-660)	52.48		0.23	